This document is guaranteed to be current only to issue date.

Some Mars Global Surveyor documents that relate to flight operations are under revision to accommodate the recently modified mission plan.

Documents that describe the attributes of the MGS spacecraft are generally up-to-date.

542-409, Vol. 3.

MARS GLOBAL SURVEYOR
Mission Operations Specification

Volume 3: Operations

FINAL

Jet Propulsion Laboratory
California Institute of Technology

SEPTEMBER, 1995

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Mars Global Surveyor
Mission Operations Specification

Volume 3: Operations

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FINAL

Jet Propulsion Laboratory
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SEPTEMBER,1995

Table of Contents

VOLUME 3 FIGURE LIST

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document defines the processes required to support the Mars Global Surveyor mission operations.

Section 2, " MOS Processes" describes the processes specified in Mission Operations Specification Volume 1, System.

Section 3, "Organization," defines the flight operations team and team positions required to execute those processes.

This document does not levy operational requirements on the launch vehicle. It formally covers operations from initial Deep Space Network (DSN) acquisition of the Mars Global Surveyor spacecraft signal and ends with the End of Prime Mission (EOPM).

Aerobraking operations have been included in this document as Appendix A.

1.2 DOCUMENT CHANGE CONTROL

This document is planned to be used during the entire project. All changes to it shall be made in accordance with the project controls defined in 542-15, Mars Global Surveyor Documentation Plan. Revisions will be by pages and revised issues, as appropriate.

All changes to this document shall be reviewed by the Telecommunications and Mission Operations Directorate Representative(s) and approved by the Mars Global Surveyor Mission Manager.

1.3 REFERENCED DOCUMENTS

(1) Mission Operations Specification, Vol. 1, System (542-409 Vol. 1)

(2) Mission Operations Specification, Vol. 2, Data System (542-409 Vol.2)

(3) Mission Operations Specification, Vol. 4, Procedures (542-409 Vol. 4)

(4) Mission Operations Specification, Vol. 5, Interfaces (542-409 Vol. 5)

(5) Mission Plan (542-405)

(6) Navigation Plan (542-406)

(7) Project Data Management Plan (542-403)

(8) Science Data Management Plan (542-310)

(9) Project Security Requirements (542-111)

(10) TMOD Physical and Automated Information Security (IOM-RP-5/95- Rev.A)

(11) Mars Global Surveyor Documentation Plan (542-15)

(12) Mission System Configuration Management Plan (542-412)

(13) JPL Data Systems Resource Allocation Process (JPL D-2005, to be published)

(14) DSN Detailed Interface Design Document (820-13)

(15) Detailed Mission Requirements (DMR) Document (542-424)

SECTION 2

MISSION OPERATIONS SYSTEM (MOS)PROCESSES

2.0 OPERATIONS PROCESSES

MOS Specification, Volume 1, System describes the Mission System Process (see Figure 2-0) and places requirements on the following processes.

2.1 UPLINK PROCESS

The uplink process produces all command files sent to the spacecraft. The process map is shown in Figure 2-1. There are four principal subprocesses in the uplink process: stored sequence generation, non-stored command generation, command radiation and command verification. Uplink process improvement is a secondary subprocess that continues throughout the life of the project.

Stored sequences are loaded in the C&DH memory for later execution. Non-stored commands are executed immediately after receipt by the spacecraft. Non-stored commands are classified by the level of processing they require before being approved for radiation to the spacecraft.

Uplink process inputs include the Mission Plan, Navigation Plan, Mission Sequence Plan, Spacecraft Activity Sequence Files (SASFs), command verification data, Resource Allocation Files and spacecraft state.

Uplink process outputs include time ordered listings (TOLs), commands files and change requests.

The uplink process is dependent on the following new technologies: autonomous eclipse management, automated command toolkit, automated sequence review software, shell-driven sequence software, telemetry test & command system, automated scheduling tools and automated testbed setup.

2.1.1 Stored Sequence Process

The Stored Sequence development process is a two pass process requiring 6 weeks to complete. Pass 1 requires 5 weeks and begins with a three week duration sequence planning phase, followed by a short sequence integration phase and ends with a sequence review and simulation run. Pass 2 immediately follows Pass 1 and includes a rerun of the sequence to accomodate comments of a corrective nature found during the Pass 1 review and simulation run, to implement approved change requests and to incorporate approved late updates (e.g. maneuver parameters) to the sequence. Figure 2-2 provides a graphical representation of the stored sequence development process.

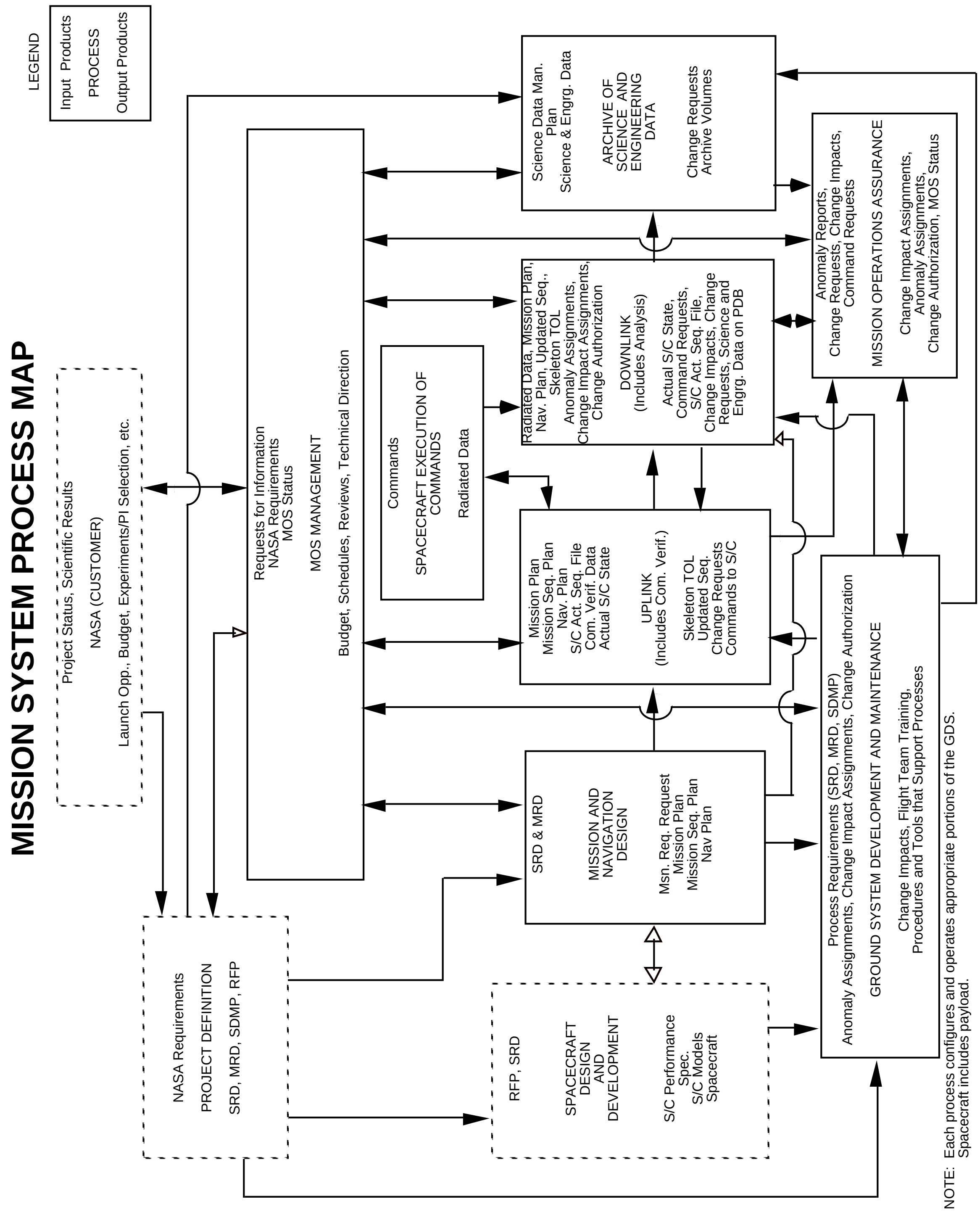
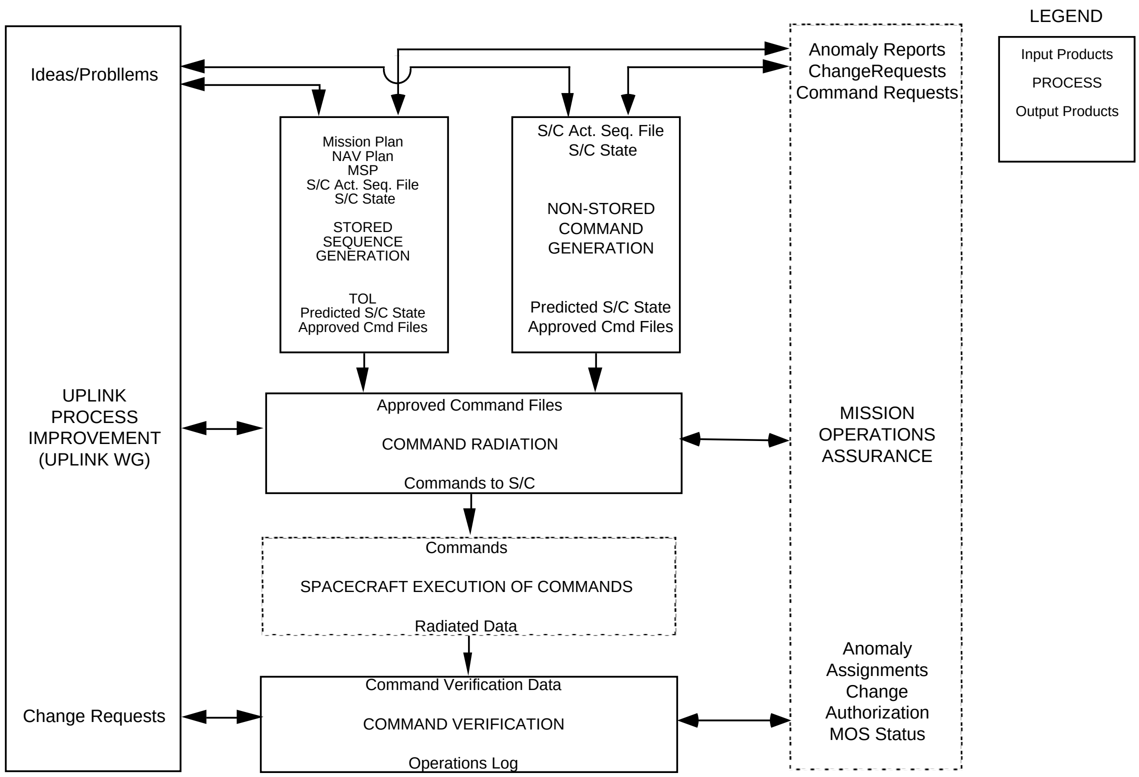

MISSION SYSTEM PROCESS MAP
LEGEND
Input Products
PROCESS
Output Products
Project Status, Scientific Results
NASA (CUSTOMER)
Launch Opp., Budget, Experiments/PI Selection, etc.
Requests for Information
NASA Requirements
MOS Status
MOS MANAGEMENT
Budget, Schedules, Reviews, Technical Direction
Commands
SPACECRAFT EXECUTION OF COMMANDS
Radiated Data
Science Data Man. Plan
Science & Engrg. Data
ARCHIVE OF SCIENCE AND ENGINEERING DATA
Change Requests
Archive Volumes
Radiated Data, Mission Plan, Nav. Plan, Updated Seq., Skeleton TOL
Anomaly Assignments, Change Impact Assignments, Change Authorization
DOWNLINK
(Includes Analysis)
Actual S/C State, Command Requests, S/C Act. Seq. File, Change Impacts, Change Requests, Science and Engrg. Data on PDB
Anomaly Reports, Change Requests, Change Impacts, Command Requests
MISSION OPERATIONS ASSURANCE
Change Impact Assignments, Anomaly Assignments, Change Authorization, MOS Status
Mission Plan
Mission Seq. Plan
Nav. Plan
S/C Act. Seq. File
Com. Verif. Data
Actual S/C State
UPLINK
(Includes Com. Verif.)
Skeleton TOL
Updated Seq.
Change Requests
Commands to S/C
Process Requirements (SRD, MRD, SDMP)
Anomaly Assignments, Change Impact Assignments, Change Authorization
GROUND SYSTEM DEVELOPMENT AND MAINTENANCE
Change Impacts, Flight Team Training, Procedures and Tools that Support Processes
SRD & MRD
MISSION AND NAVIGATION DESIGN
Msn. Req. Request
Mission Plan
Mission Seq. Plan
Nav Plan
NASA Requirements
PROJECT DEFINITION
SRD, MRD, SDMP, RFP
RFP, SRD
SPACECRAFT DESIGN AND DEVELOPMENT
S/C Performance Spec.
S/C Models
Spacecraft
NOTE: Each process configures and operates appropriate portions of the GDS. Spacecraft includes payload.

Figure 2-0

UPLINK PROCESS MAP

PROCESS INPUTS: Mission Plan, NAV Plan, Mission Sequence Plan, S/C Act. Seq. File, Command Verification Data, S/C State



PROCESS OUTPUTS: Change Requests, Commands to Spacecraft, Predicted S/C State, TOL

Figure 2-1

2.1.1.1 Pass 1

Pass 1 of the stored sequence development process begins with a three week period during which the Mission Planner and Sequence Team Sequence Integration Engineer (SIE) work together to construct a time ordered list (TOL) for the sequence based on the Mission Sequence Plan (MSP) and current spacecraft status and DSN allocations. During this period, the SIE responsible for the sequence in question will build the TOL and will then release it to the Spacecraft Team (SCT) so that they may populate the TOL with any additional commands deemed necessary. After the Spacecraft Team completes their processing, they shall return the TOL to the Sequence Team (SEQ) to complete processing of the sequence.

Upon return of the sequence to the SEQ a detailed integration of the sequence will take place. This will require four (4) workdays to complete. This process will produce various sequence products including, but not limited to, a Spacecraft Activity Sequence File (SASF), Enhanced Predicted Events File (EPEF) and Ground Command File (GCMD) as well as other sequence review products.

Pass 1 ends with two activities which occur concurrently. The first of these two activities is the flight team review of the sequence requiring five (5) workdays. The first two (2) days of this review will be devoted to reviewing the sequence for simulation run approval. At the close of the second day of the review the Mission Manager shall approve or disapprove the sequence for processing through the STL. If approval is granted, then the Spacecraft Team shall begin the sequence simulation run. This simulation run has a duration of three workdays and begins at the start of business on the third day of the sequence review. The output from these two activities will be a set of sequence review comments and any approved sequence change.

2.1.1.2 Pass 2

Pass 2 of the sequence development process is intended to be used to incorporate approved modifications and corrections identified during the Pass 1 review and simulation run. Additionally, final maneuver parameter specification will be permitted at this time.

The first step in Pass 2 is for the SEQ to collect all review comments and approved change requests. Final manuver parameter specification will be provided to the SEQ by the SCT at the beginning of Pass 2. Upon assembly of all inputs, the SEQ shall incorporate these inputs into the SASF released from Pass 1. All SEQ software will be run on the updated sequence files. Output for review and eventual radiation to the spacecraft shall be generated by the SEQ and made available for flight team review. This step shall require two workdays to complete.

The second step in Pass 2 will be a two day duration flight team sequence review during which flight team members shall use the sequence review products released by the SEQ during the preceding step. This review will end the nominal sequence development process. Upon completion of the final review, the sequence will be ready for approval at a command conference and radiation to the spacecraft. However, a short contingency rerun period is available following the final review. This rerun will only be exercised if the sequence contains errors which will endanger the health of the spacecraft and cannot be corrected using non-stored commands. This contingency rerun is composed of a one day duration sequence correction step followed by a one day review period.

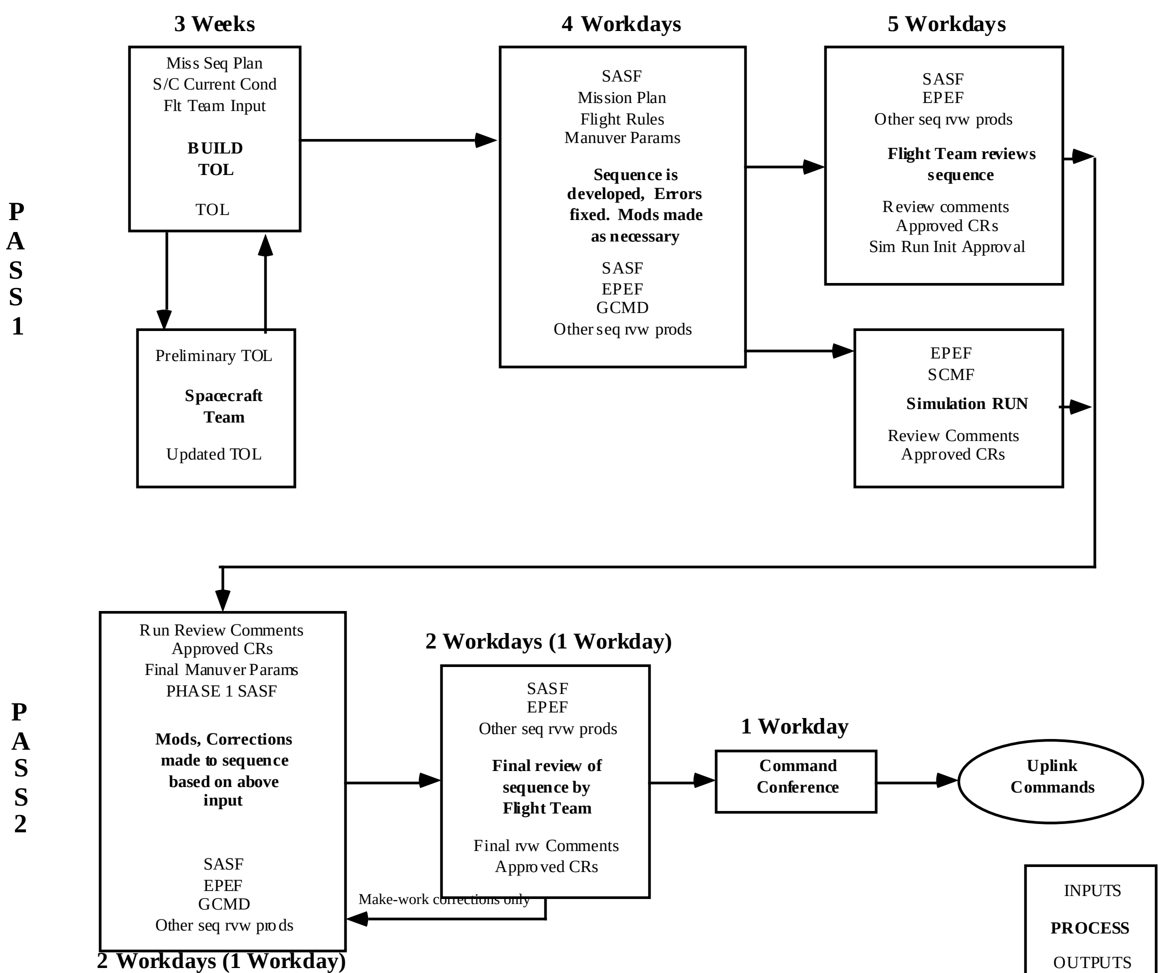


Figure 2-2
Stored Sequence Development Process

2.1.2 Non-Stored Commanding Process

Non-stored commanding (NSC) will be used as a supplementary method of spacecraft control. As its name implies, non-stored commanding involves the sending of commands to the spacecraft which are not stored in onboard bus memory, but rather are executed immediately upon receipt by the spacecraft.

Non-stored commands are categorized into four subtypes and are grouped according to the level of processing they require. These are Non-interactive Payload Commands (NIPC), Express Commands (EC), Coordinated Commands (these include spacecraft and MOS interactive commands) and Pre-Approved Commands (PAC). Each type of NSC has a defined amount of rigor applied to its processing. NIPCs are processed with the least amount of flight team rigor. This is a result of their non-interactive nature. The processing of ECs, Coordinated Commands and PACs is more rigorous because of their interactive nature and the possibility that such commands could damage the spacecraft or an instrument, resulting in loss of data or mission goals.

Non-stored commands will be initiated by members of the flight team. In the case of NIPCs, the science teams will create the SASFs containing their desired commands. As for ECs, Coordinated Commands and PACs, the SCT will create the necessary SASF. After the requesters install their SASFs onto the PDB, the SEQ will retrieve the files and prepare them for transmission to the spacecraft. The processing of NSCs will be extremely automated. NIPC (for science requesters) and EC (for engineering activities) processing will be fully automated and will require approximately ten minutes to process an SASF extracted from the PDB into a GCMD ready for transmission to the spacecraft. The NIPC and EC processes shall require little or no hands-on interaction beyond the requester installing their file onto the PDB. Coordinated Commands processing will require some hands-on interaction with their processing, however this manipulation will be reduced to only that level necessary to accomplish the processing and mitigate risk of erroneous or inappropriate commands reaching the spacecraft. The Coordinated Command process shall require between 2 hours and 8 hours to process an SASF from extraction from the PDB into a GCMD ready for transmission to the spacecraft. The variability of the duration of this process is a result of the need for STL testing of the command request. Figure 2-3 presents graphically the four NSC process flows.

2.1.2.1 Non-interactive Payload Commands (NIPC)

The science instruments shall be commanded using non-stored instrument commands. These non-interactive payload commands (NIPC) shall be initiated by the instrument teams, processed by the SEQ team and finally radiated to the spacecraft by the RTOT.

The NIPC process shall begin with the science team member installing their SASF onto the Project Database (PDB). They shall also send an e-mail message to the SEQ. This e-mail message shall be an electronic File Release

Form (FRF) containing information pertinent to the file and its retrieval from the PDB by the SEQ.

Sequence processing shall be performed using a fully automated script which is initiated by use of a UNIX daemon triggered by the e-mail FRF sent by the requester. The script shall retrieve the SASF from the PDB and immediately convert the SASF into a GCMD using the standard SEQ software tools (SEQGEN, SEQTRAN, COMMAND). If errors are encountered during this processing, then the SEQ script shall notify the requester of the circumstances surrounding the failure of the file to complete processing. If the script completes successfully, then the script shall inform the requester and the GCMD shall be installed by the script onto the PDB. The script shall then inform the RTOT that the GCMD is available on the PDB.

The NIPC process shall require no more than ten minutes per file to complete starting with the daemon triggered script retrieval of the SASF from the PDB and ending with installation of the GCMD onto the PDB. This process shall be available to the science teams 24 hours/day7 days/week, but is fully supported only on workdays from 8:00am until 4:45pm Pacific time.

It should be noted that, as mentioned above, the NIPC process is fully automated, removing the need for a SEQ member to initiate the script. This automation will be the standard procedure used for NIPC processing. However, a backup method will exist whereby the same script initiated by the daemon could be run manually if necessary. This manual operation of the script would be performed by a SEQ member but would extend the time necessary to process each file.

2.1.2.2 Coordinated Commands

Coordinated Commands include two subtypes of commands. These subtypes are MOS Interactive Commands (MOSIC) and Spacecraft Interactive Commands (SCIC).

2.1.2.2.1 MOS-interactive Commands (MOSIC)

MOS Interactive Commands (MOSIC), though not spacecraft interactive, are commands that require use of MOS resources or special handling by the MOS. This may include, but not be limited to, extremely large request files which will require long processing times, special timing of command radiation or special coordination of the radiation of the file.

The MOSIC process begins with the requester creating the SASF for their request and installing it onto the PDB. The requester then sends an e-mail File Release Form (FRF) to the SEQ containing pertinent information about the SASF. The requester also initiates a Command Request Form (CRF) which is the formal request of the activity.

The requester shall attend the Command Planning Meeting (CPM) to submit the request for their activity. During the CPM all special coordination and consideration of the activity shall be completed. CPM attendees shall include the Uplink Operations Engineer, the requester, a SEQ team representative, a RTOT representative and a SCT representative (via telecon, as appropriate).

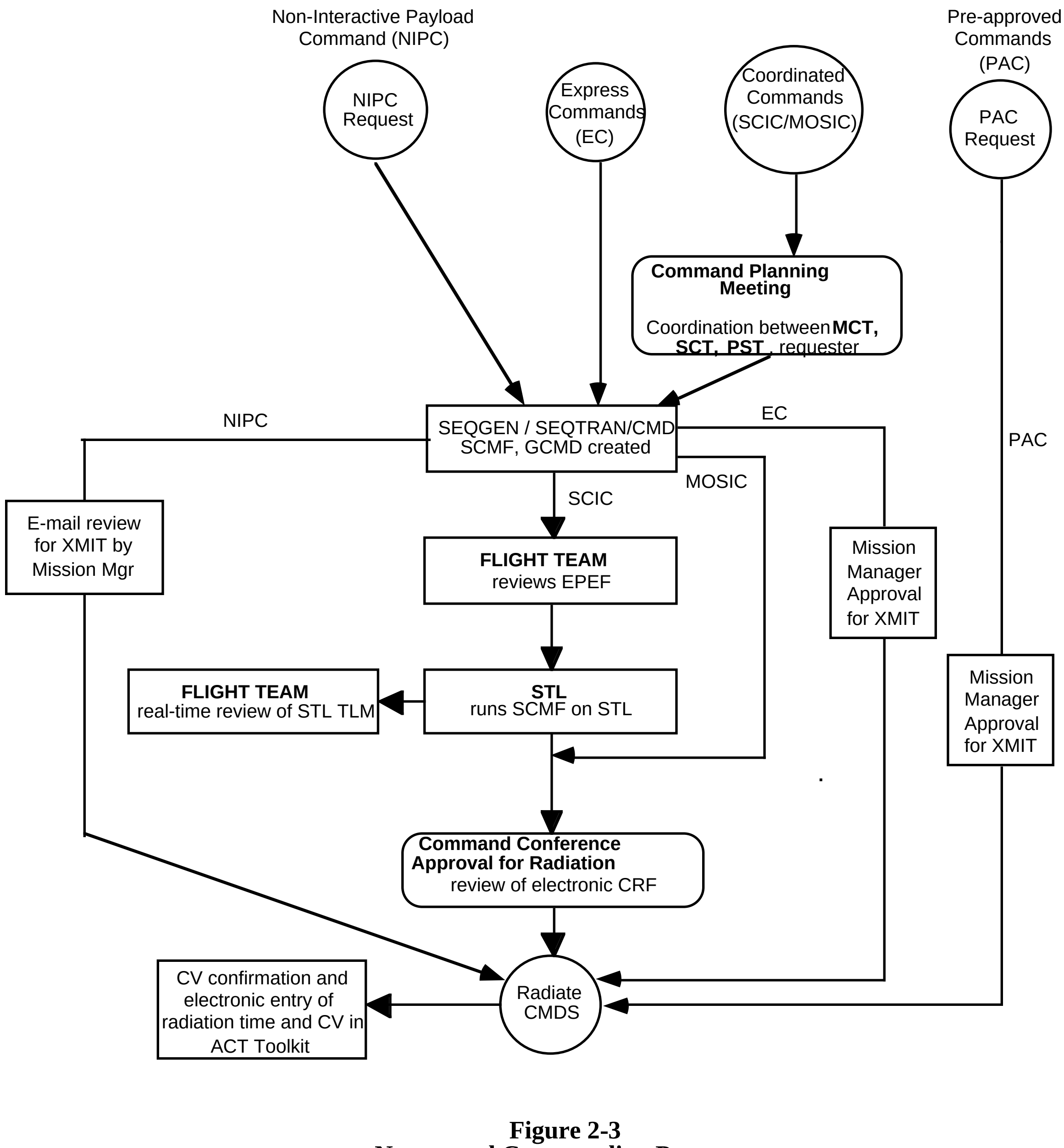


Figure 2-3
Non-stored Commanding Processes

After the CPM the SEQ shall retrieve the SASF from the PDB and immediately initiate the MOSIC processing script which will convert the SASF into a GCMD. If errors are encountered during this processing, then the SEQ shall notify the requester and RTOT of the circumstances surrounding the failure of the file to complete processing. If the script completes successfully, then the SEQ shall inform the requester of such and the GCMD shall be installed by the SEQ onto the PDB. The SEQ shall then complete those portions of the CRF requiring completion at this step. The SEQ shall then inform the RTOT that the GCMD is available on the PDB.

Following the completion of SEQ processing and appropriate notifications, the CRF shall be submitted to the Command Conference for radiation approval by the Mission Manager. Attendees of the Command Conference shall be the Mission Manager, SEQ Team Chief, Requester, RTOT Chief and Spacecraft Team representative. Any non-JPL resident representatives (Requester or Spacecraft Team representative) will participate this meeting via telecon, as necessary.

Upon Command Conference approval of the request the RTOT shall retrieve the GCMD from the PDB and radiate the commands to the spacecraft.

The duration of the MOSIC process will depend upon the degree of MOS interaction associated with each request. Some may only require minimal interaction and, therefore, require no more than fifteen minutes to complete processing. Others may require several hours to complete due to size or complexity of the request. The duration for each request shall be determined during the Command Planning Meeting.

2.1.2.2.2 Spacecraft-interactive Commands (SCIC)

Spacecraft-interactive commands, as their name implies, are interactive with a spacecraft subsystem. This interaction is with, but not limited to, power, thermal or onboard memory. Because of their interactive nature, SCICs require much more scrutiny and analysis by the flight team before they are sent to the spacecraft. This extra care is exercised to avoid damage to or loss of the spacecraft through miscommanding.

The SCIC process begins with the SCT constructing a SASF containing the desired commands. After completion of the SASF by the SCT they shall install the file onto the PDB. They shall also send an e-mail File Release Form (FRF) to the SEQ containing pertinent information regarding the SASF. Finally, the SCT shall initiate a CRF which is the formal request for the activity.

The SCT shall submit the request to the Command Planning Meeting (CPM). During the CPM the request shall be coordinated for processing, testing and radiation to the spacecraft. Attendees of the CPM shall include the SEQ Team Chief, a SCT representative, a SEQ representative and an RTOT representative. The CPM will result in approval for generation and testing of the commands and a plan for full implementation of the request.

The SEQ shall retrieve the SASF from the PDB and initiate the SCIC processing script. This script shall create as output both a GCMD containing the requested commands and an Enhanced Predicted Events File (EPEF) containing the requested commands merged with the stored sequence during which they will execute. The SEQ shall then install the EPEF, SCMF and GCMD onto the PDB and notify the SCT that they are ready for review and testing in the STL. The SEQ shall complete those portions of the CRF for which they are responsible and return the CRF to the SCT via the PDB.

The SEQ shall review the merged EPEF and other sequence review products. If errors are found, then the SEQ shall notify the SCT of the errors.

Upon release of the EPEF, SCMF and GCMD by the SEQ, the SCT shall retrieve the EPEF and SCMF from the PDB and begin their processing. First the SCT shall review the merged EPEF for errors. If errors are found, they shall notify the SEQ Team Chief, and shall halt any preparations being made for the STL run. If no errors are found in the EPEF review, then the SCT shall initiate the loading of the SCMF containing the requested commands into the STL. After successful loading, the SCT shall begin the actual run of the commands.

As the STL is running, the SCT shall monitor the STL telemetry in real-time to verify the correct execution of the commands. Any errors found during this run shall be reported to the SCT member responsible for the request and to the SEQ Team Chief. If errors are found, then the SCT shall halt all further processing of the command file and correct the errors. The corrected file(s) will then be resubmitted for processing by the above teams and processes. If no errors are found during the STL run then the SCT shall complete all necessary information on the CRF.

Upon successful completion of all the above processing with no errors, the SCT shall bring the request to the Command Conference for radiation approval by the Mission Manager. Attendees of the Command Conference shall be the Mission Manager, SEQ Team Chief, SCT representative and RTOT Chief.

Upon Command Conference approval of the request, the RTOT shall retrieve the GCMD from the PDB and use the command radiation procedure to send the commands to the spacecraft.

The duration of the SCIC process, from the beginning of the CPM to the conclusion of the Command Conference shall nominally be seven hours. This shall include thirty minutes for the CPM, thirty minutes for SEQ command file processing, one hour for SCT review of the EPEF, a concurrent SEQ review of both the EPEF and SCMF requiring two hours, a three hour STL run and one hour for the Command Conference.

2.1.2.3 Express Commands (EC)

Express Commands (EC) shall be used by the project as a contingency method for commanding. ECs are not put through the usual generation processes for checking such as the flight team review. Consequently, there is inherently higher risk of sending an erroneous command to the spacecraft resulting in damage to or loss of mission goals or the spacecraft. However, the turnaround time associated with this type of commanding can be very small, making it attractive during times when a quick response is necessary to avoid imminent loss of or damage to the spacecraft. ECs shall be used only in response to anomalies, for time urgent commanding or in situations where coordinated commanding is not possible within one day of the command being sent (e.g. aerobraking commands).

The EC process shall begin with the SCT installing a SASF onto the Project Database (PDB). They shall also send an e-mail message to the SEQ. This e-mail message shall be an electronic FRF containing information pertinent to the file and its retrieval from the PDB by the SEQ.

SEQ processing shall be performed using a fully automated script which is initiated by use of a UNIX daemon triggered by the e-mail FRF sent by the SCT. The script shall retrieve the SASF from the PDB and immediately convert the SASF into a GCMD using the standard SEQ software tools (SEQGEN, SEQTRAN, COMMAND). SEQGEN simulation shall also include merging the requested commands into the currently ongoing sequence. If errors are encountered during this processing, then the SEQ script shall notify the requester of the circumstances surrounding the failure of the file to complete processing. If the script completes successfully, then the script shall inform the SCT and the GCMD shall be installed by the script onto the PDB. The script shall then inform the RTOT that the GCMD is available on the PDB.

The EC process shall require no more than fifteen minutes per file to complete starting with the SEQ script retrieval of the SASF from the PDB and ending with the installation of the GCMD onto the PDB. This process shall be available to the SCT every day, twenty-four hours per day.

It should be noted that, as mentioned above, the MOS is using a fully automated process, removing the need for a SEQ member to initiate the script. This automation will be the standard procedure used for EC processing. However, a backup method will exist whereby the same script initiated by the daemon could be run manually if necessary. This manual operation of the script would be performed by a SEQ member but would extend the time necessary to process each file.

2.1.2.4 Pre-Approved Commands (PAC)

The final class of commands available to the MGS flight team are Pre-Approved commands. These are command files which have been processed and approved using the Coordinated Command process (SCIC or MOSIC) and are stored “on-the-shelf” for future use. The basic process for generating these commands will be, for the first time through, to process them as appropriate using either the SCIC or MOSIC subprocess described above. The command file will then be identified as “reusable” by the approving authority and will then be kept “shelved” for future use. PACs can be sent by subsystem level personnel without SCT Chief approval each time the commands are radiated.

However, these commands must be approved for reradiation by the Mission Manager prior to their being resent. The “pre-approval” of these files pertains to their having been used once and, therefore, not requiring an additional pass through the entire Coordinated Command process. In addition, these command files may only contain a certain class of SCIC. An example of these commands may include simple heater on/off commands.

2.1.3. Command Radiation

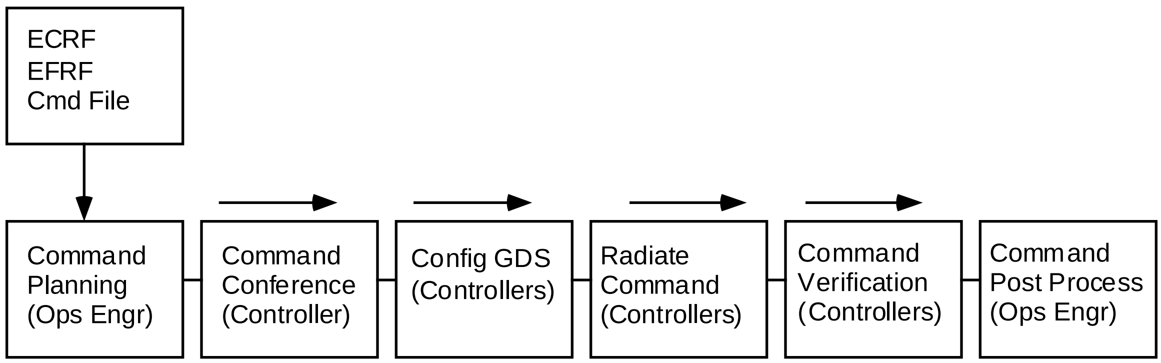


Figure 2-4   Real-Time Operations Team Command Radiation and Verification

Figure 2-4 shows that upon receipt of an Electronic File Release Form, Command Request Form and radiatable binary file from the SEQ via thePDB, the Real-Time Operations Team (RTOT) shall ensure that all ground data system resources are available, coordinate with the DSN station(s), and schedule the file for radiation according to Project operational procedures (specified in MOS Specification, Volume 4, Procedures).

The Real-Time Operations Team shall confirm receipt of the command by the spacecraft and log all particulars associated with the session for post-real-time analysis.

As of MGSO CMD version 19, the Command system has been broken into a number of modular stand-alone processes. This enables fewer command radiation errors and higher automation and throughput. The Real-Time Operations Team shall develop required end-user scripts, files and user interfaces.

The specifics of these activities are defined in the Operating Plans for the Real-Time Operations Team later in this volume.

2.2 DOWNLINK PROCESS

The Downlink process includes five principle subprocesses: Navigation Analysis (NA), Flight System Performance Analysis (FSPA), Ground System

Monitor, Control and Configuration (GSMCC), Science Data Analysis (SDA) and Flight Software Analysis (FSA). The process map is shown in Figure 2.5.

Downlink process inputs include the Mission Plan, Navigation Plan, Mission Sequence Plan and telemetry and radiometric data from the spacecraft.

Spacecraft telemetry (including packetized science data) and Monitor data are acquired and placed in thePDB. Along with other supporting operational data, this data (from the PDB) is input to the Navigation Analysis, the Flight System Performance Analysis, the Science Data Analysis and the Flight Software Analysis subprocesses.

Downlink process outputs include spacecraft, instrument and ground system state/status definition, Spacecraft Activity Sequence Files (SASFs), Sequence of Events files, DSN Keywords files, change requests and command requests.

The execution of the Downlink process has been allocated to the RTOT, SCT, and the SOT (for the execution of the Science Data Analysis subprocess). This allocation is defined in Section 3, Organization.

The specific functions performed in the Downlink process are defined below.

2.2.1 Ground System Monitor, Control and Configuration

Figure 2.6 illustrates how the Ground System Monitor, Control and Configuration provides all processes, services and support to input a committed set of multimission ground resources and create a calibrated, MGS activity-specific string for real-time operations.

Reengineering, enabling technology, on-going protoflighting and commercial and public domain software are all employed to streamline and automate Ground Data System operations with the intent of error minimization and effective human resource utilization. Also, Mars Pathfinder has developed a number of MGS-adaptable tools which will be modified and used.

The Real-Time Operations Team performs the Ground System Monitor, the Control and Configuration processes, functions and services.

Ground System Monitor, Control and Configuration also includes identifying, characterizing and responding to anomalies and incidents in real-time. Predict vs actuals residuals limit checking shall be automated as the quality of the predicts allows. Predicts are generated by the RTOT using the Sequence of Events Generator Subsystem. SEGS integrates predicts from many sources and distributes them to the DSN, MGSO, Mission Control and Project operations who each use them to automatically configure their resources.

The specifics of these activities are defined in the Operating Plans for the RTOT later in this volume.

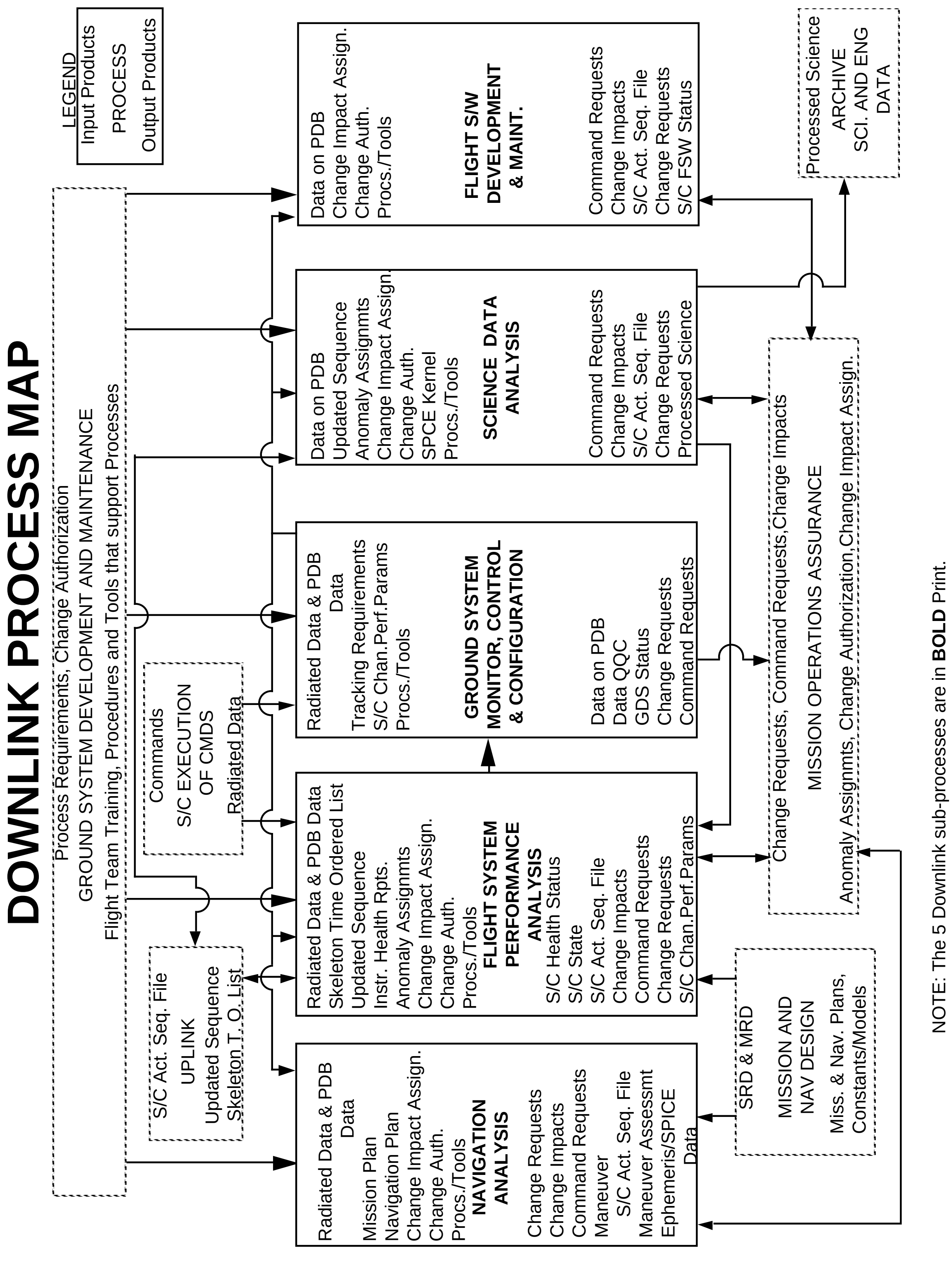
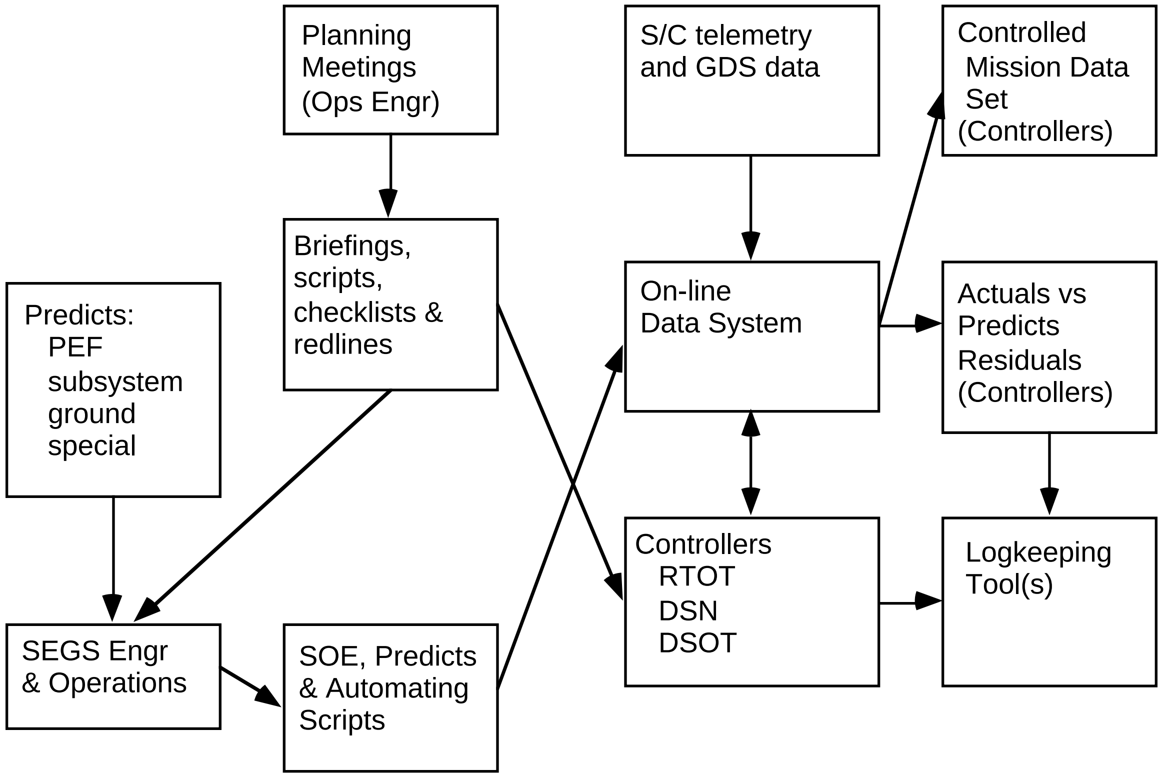

DOWNLINK PROCESS MAP
LEGEND
Input Products
PROCESS
Output Products
Process Requirements, Change Authorization
GROUND SYSTEM DEVELOPMENT AND MAINTENANCE
Flight Team Training, Procedures and Tools that support Processes
S/C Act. Seq. File
UPLINK
Updated Sequence
Skeleton T. O. List
Commands
S/C EXECUTION OF CMDS
Radiated Data
Radiated Data & PDB Data
Mission Plan
Navigation Plan
Change Impact Assign.
Change Auth.
Procs./Tools
NAVIGATION ANALYSIS
Change Requests
Change Impacts
Command Requests
Maneuver S/C Act. Seq. File
Maneuver Assessmt
Ephemeris/SPICE Data
Radiated Data & PDB Data
Skeleton Time Ordered List
Updated Sequence
Instr. Health Rpts.
Anomaly Assignmts
Change Impact Assign.
Change Auth.
Procs./Tools
FLIGHT SYSTEM PERFORMANCE ANALYSIS
S/C Health Status
S/C State
S/C Act. Seq. File
Change Impacts
Command Requests
Change Requests
S/C Chan.Perf.Params
Radiated Data & PDB Data
Tracking Requirements
S/C Chan.Perf.Params
Procs./Tools
GROUND SYSTEM MONITOR, CONTROL & CONFIGURATION
Data on PDB
Data QQC
GDS Status
Change Requests
Command Requests
Data on PDB
Updated Sequence
Anomaly Assignmts
Change Impact Assign.
Change Auth.
SPCE Kernel
Procs./Tools
SCIENCE DATA ANALYSIS
Command Requests
Change Impacts
S/C Act. Seq. File
Change Requests
Processed Science
Data on PDB
Change Impact Assign.
Change Auth.
Procs./Tools
FLIGHT S/W DEVELOPMENT & MAINT.
Command Requests
Change Impacts
S/C Act. Seq. File
Change Requests
S/C FSW Status
SRD & MRD
MISSION AND NAV DESIGN
Miss. & Nav. Plans, Constants/Models
Change Requests, Command Requests,Change Impacts
MISSION OPERATIONS ASSURANCE
Anomaly Assignmts, Change Authorization,Change Impact Assign.
Processed Science
ARCHIVE SCI. AND ENG DATA
NOTE: The 5 Downlink sub-processes are in BOLD Print.

FIGURE 2-5



REAL-TIME OPERATIONS TEAM
DOWNLINK OPERATIONS
FIGURE 2-6

2.2.2 Flight System Performance Analysis

2.2.2.1 Process Overview

The Flight Systems Performance Analysis (FSPA) process, shown in figure 2-7, is a subprocess of the Downlink process shown in figure 2-5. The FSPA process is highly interactive with other processes internal and external to the Downlink process. This interactivity includes, but is not limited to, support to the Uplink Process, identification and resolution of anomalies to the Mission Operations Assurance Process, support and implementation to the Flight Software Development and Maintenance Process, usage and testing of ground system software and tools, and coordination with Project management.

The objectives of the FSPA process during normal operations are to:
a) analyze spacecraft telemetry to assess performance and health, and
b) review and validate command activities relative to the current spacecraft capabilities.

The performance and health analysis takes place in both realtime (using current telemetry) and non-realtime (using playback data from the spacecraft's solid state recorders or data stored in the PDB). Command activity validation entails assessing the capability of the spacecraft to successfully and safely execute the stored sequence commands and non-stored command files to be uplinked. Validation includes checking for spacecraft constraint violations and reviewing simulation data from the STL for critical or "first-time" spacecraft activities. The objectives of the FSPA process for off-nominal operations are to develop contingency plans and properly respond to anomaly situations.

These objectives are met using FSPA subprocesses:

1) Real Time Health and Performance Assessment,
2) Non-Real Time Performance Assessment, and
3) Anomaly Planning, Analysis and Resolution.

These subprocesses are described in the following sections.

2.2.2.2 Input and Output Products

As depicted in the FSPA Process Map in figure 2-7, the primary input to all three subprocesses is spacecraft telemetry. This telemetry includes engineering measurements and memory readouts, data which are necessary to analyze the health and proper performance of the flight system. The science instruments' housekeeping data are analyzed by the science team members and summary status reports are provided to the Spacecraft Team for assessment of spacecraft bus-to-instrument interfaces. Other inputs to the FSPA process include the Mission Plan, uplink products (for stored sequence and non-stored commands), ground system tools and documentation, trajectory and maneuver profile files, and MOS change requests requiring SCT assessment and impacts.

The FSPA products convey the results of the spacecraft analyses performed. Status reports and anomaly reports relay spacecraft performance and health to the rest of the project. Command requests and SASFs provide input to the uplink process for future spacecraft events. Spacecraft performance predictions and contingency plans prepare for the implementation of future spacecraft activities.

2.2.2.3 Subprocess Descriptions

2.2.2.3.1 Flight Systems Realtime Health and Performance Assessment

This subprocess (figure 2-8) provides for a rapid assessment of the health and performance of the spacecraft during periods of DSN coverage. The level of SCT subprocess support is determined by the criticality and uniqueness of the spacecraft activity. If the activity is routine or low risk to either the spacecraft or mission objectives, mission controllers will monitor the spacecraft during the

DSN pass. For first-time events or if an activity is deemed critical, appropriate SCT members as well as mission controllers monitor the activity.

For critical events, a pre-pass preparation phase reviews planned events, schedules SCT support, and ensures current documentation is available, including procedures and contingency plans. The on-line phase monitors spacecraft telemetry and ground system reports while assessing the spacecraft's health and status. In the event of a spacecraft anomaly, the Anomaly Planning, Analysis and Resolution subprocess (section 2.2.2.3.3) responds.

Enabling technology to facilitate this subprocess includes electronic control and editing of engineering channel data parameters, electronic realtime log books, electronic documentation, automatic alarm detection and notification, electronic status reporting, and an interactive, electronic anomaly reporting database.

2.2.2.3.2 Flight Systems Non-Realtime Performance Analysis

The non-real time analysis subprocess (figure 2-9) uses the ground system software to process spacecraft telemetry and assess spacecraft health, performance, and long-term trends. The software includes ground data acquisition tools (e.g., query scripts) and spacecraft performance analysis tools for data analysis (e.g., power trends, temperature profiles, spacecraft dynamics, and mass properties).

The results of these analyses allow the SCT to modify and plan future spacecraft activities in support of the uplink processes. Status reports, anomaly reports, and sequence and command requests are all outputs of this subprocess.

Interaction between the SCT and the Science Operations Team correlates the bus and instrument data to maintain proper spacecraft health and performance and spacecraft-to-instrument interfaces. Of principle interest to this interface are power, temperature, command and data flow, and spacecraft dynamics.

2.2.2.3.3 Flight Systems Anomaly Planning, Analysis and Resolution

This subprocess prepares for, identifies, and resolves spacecraft anomalies. To safely operate the spacecraft, preparation for potential spacecraft failures and fault protection responses is necessary. Prior to launch, based on the spacecraft and flight software designs, plausible anomalies are identified and contingency plans developed. The plans are kept current and new plans are developed throughout the flight as conditions warrant. This contingency planning development and maintenance effort is depicted in figure 2-10.

Contingency plans document the proposed failure scenario, its symptoms, the corresponding fault protection response (if applicable), and the failure's effects. The appropriate ground response, including a detailed order of activities, is also provided. Critical to the response is the identification and implementation of contingency commands, so specific command loads are listed and often prepared in advance and placed "on the shelf." The plan is typically validated in the STL by injection of the fault and execution of the plan's responses. Plans also typically involve other teams, especially the SEQ and RTOT. Upon approval by the Mission Manager, the plans are incorporated into the Mission Operations Specification, Volume 11.

Maintenance of onboard spacecraft parameters, especially fault protection parameters, in a known state is critical to proper anomaly response, both by the onboard algorithms and by the ground.

Actual spacecraft anomaly identification and resolution activities are specific to the situation, but typically involve a data gathering phase, a likely cause identification phase, and a response phase. If these phases show indications of requiring long-term (greater than ~12 hours) support, the SCT is divided into two shifts for 24-hour operations capability. If a contingency plan is applicable, it is invoked as soon as practical. The anomaly is documented in appropriate forms, e.g., Incident / Surprise / Anomaly and status reports.

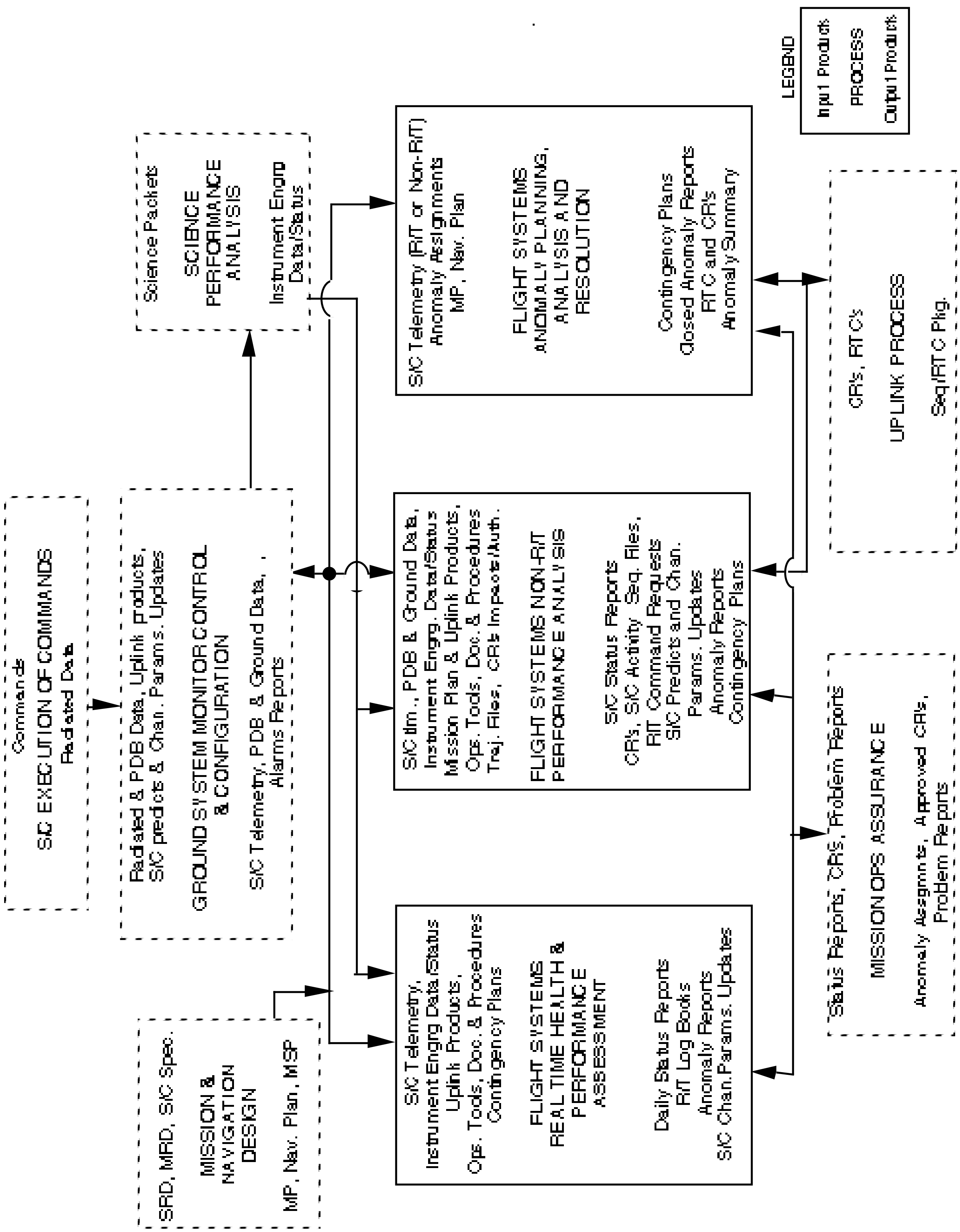


Figure 2-7. Flight Systems Performance Analysis Process Map

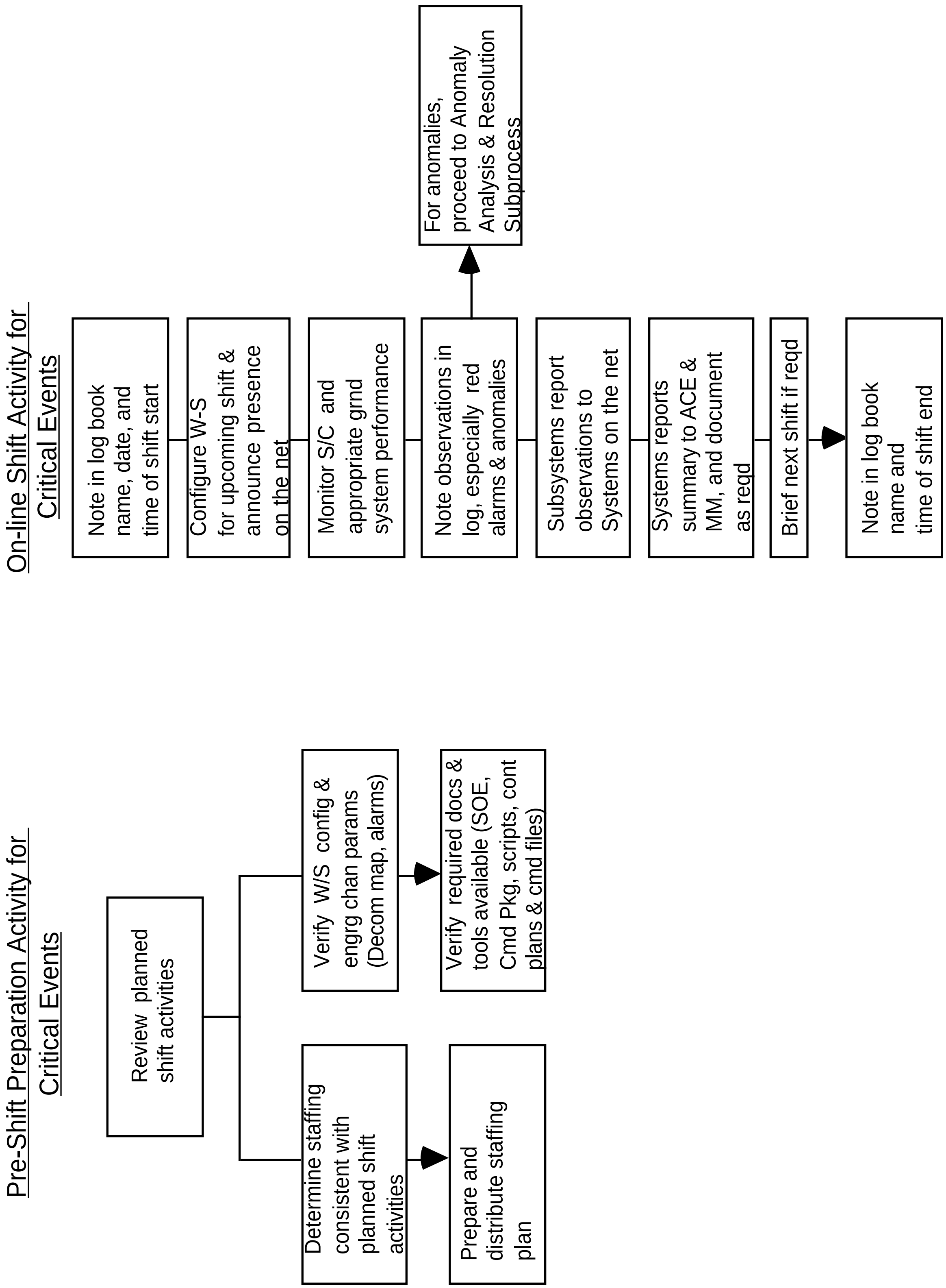


Figure 2-8. Flight Systems Realtime Health and Performance Assessment

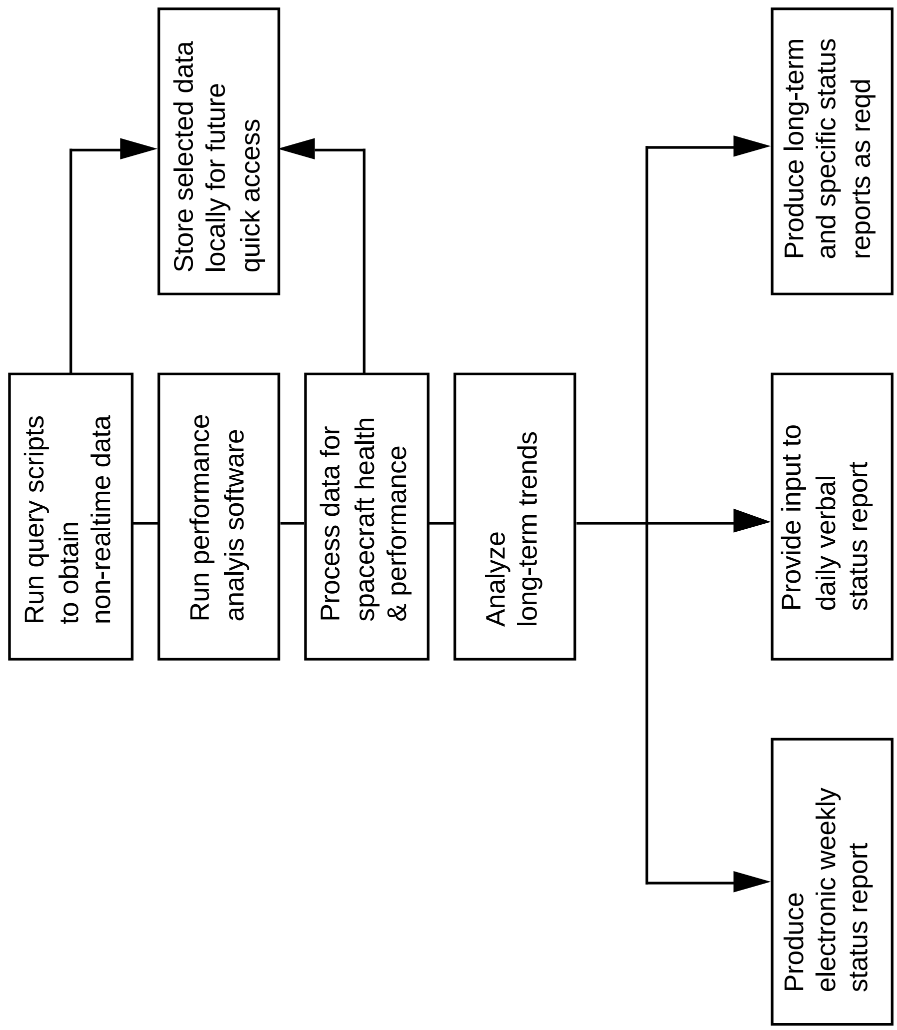


Figure 2-9. Flight Systems Non-Realtime Performance Analysis

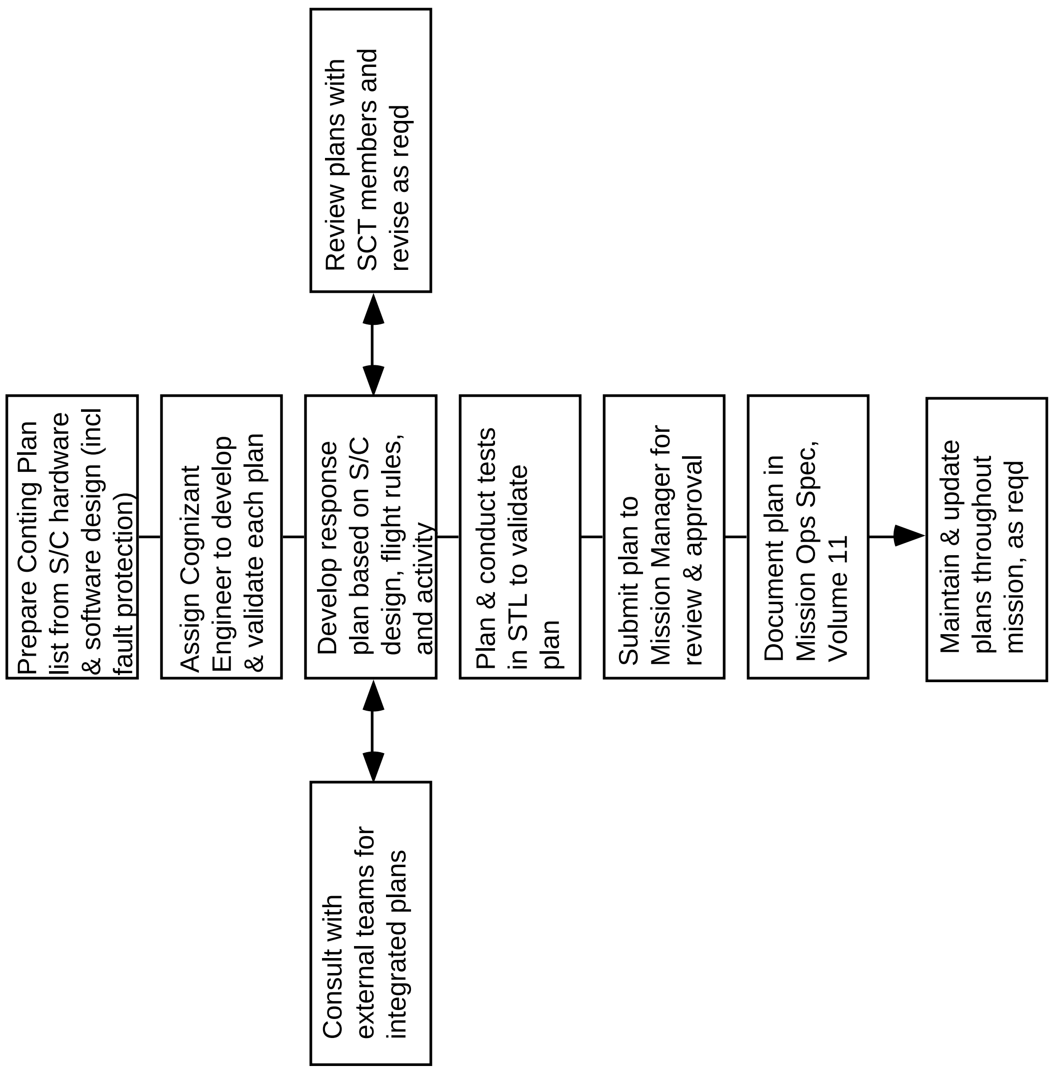


Figure 2-10. Flight Systems Anomaly Planning, Analysis and Resolution

2.2.3 Navigation Analysis

The navigation process map for flight operations is given in Figure 2-11. This shows the three navigation subprocesses: 1) orbit determination and analysis, 2) maneuver design and implementation and 3) the generation of trajectory and orbital information used by various project teams.

The maneuver design and implementation subprocess is given in Figure. 2-12 This subprocess begins after the orbit determination results, which give the current location of the spacecraft with future predictions and uncertainties, are available. With this infromation a maneuver design is computed, targeting the spacecraft to a new target-plane location (allowing capture by Mars) or targeting to a new set of orbit elements. Maneuver implementation results in a set of commands executed by the spacecraft which will allow the designed maneuver to be achieved. This set of commands is designed, converted into a sequence, tested, reviewed and finally transmitted to the spacecraft for execution at a predefined time. Once the maneuver is executed, the results are verified by the receipt of telemetry data and the evaluation of the maneuver effect by tracking data analysis.

Finally Figure 2-13 shows the process flow of the maneuver design and implementation subprocess. It involves the procedures used to slew the spacecraft to the burn attitude as specified by the navigation design and to return the spacecraft to its original attitude. Throughout this implementation process power, thermal, telecommunications and fault protection considerations are also examined. This subprocess requires a close interaction between navigators and attitude control and propulsion unit engineers. One of the final steps is to convene a formal meeting (the Maneuver Approval Meeting) of all responsible parties just prior to transmission of the maneuver sequence to the spacecraft for execution.

NAVIGATION PROCESS MAP

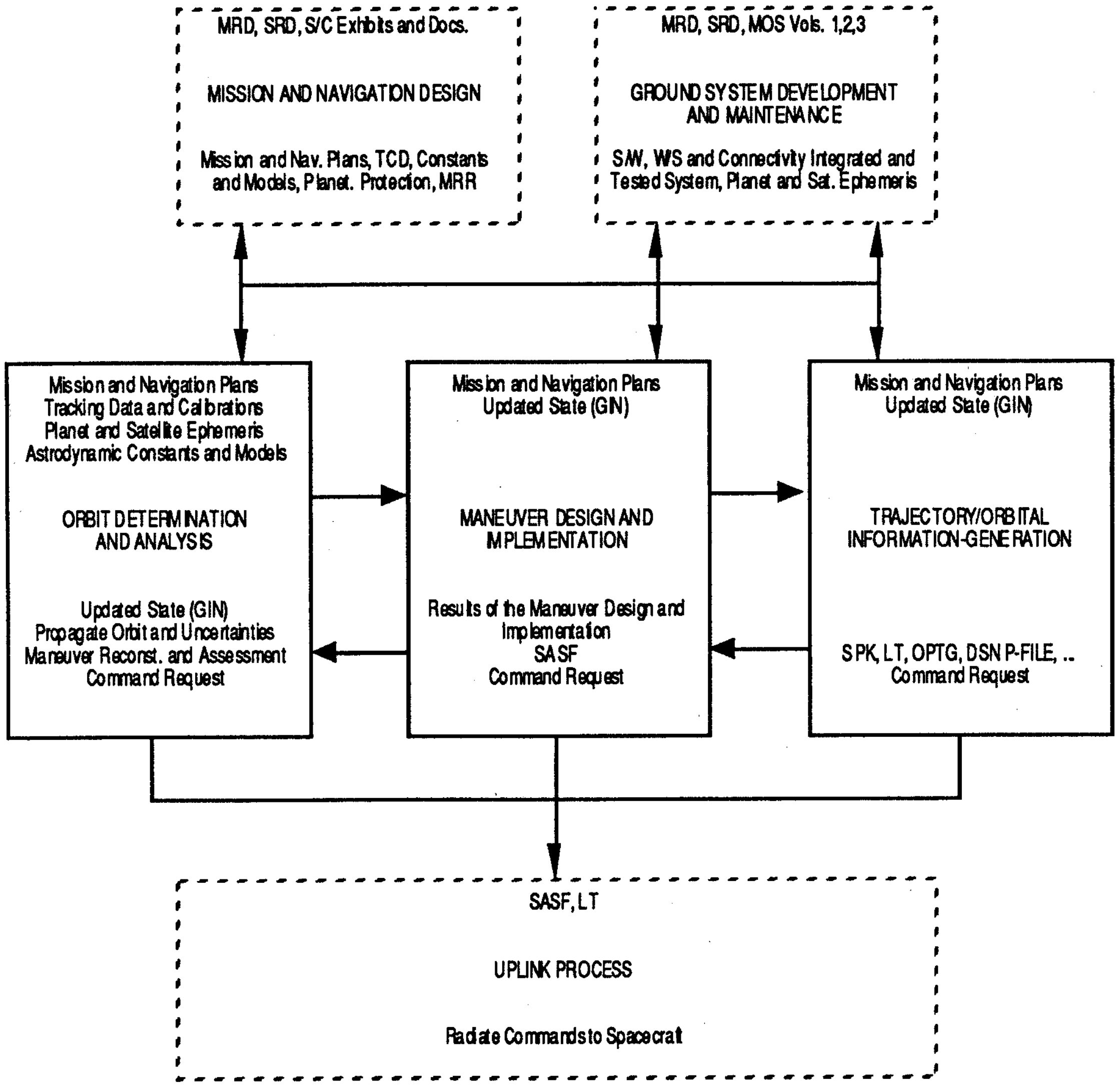


Figure 2-11

Maneuver Design & Implementation Subprocess

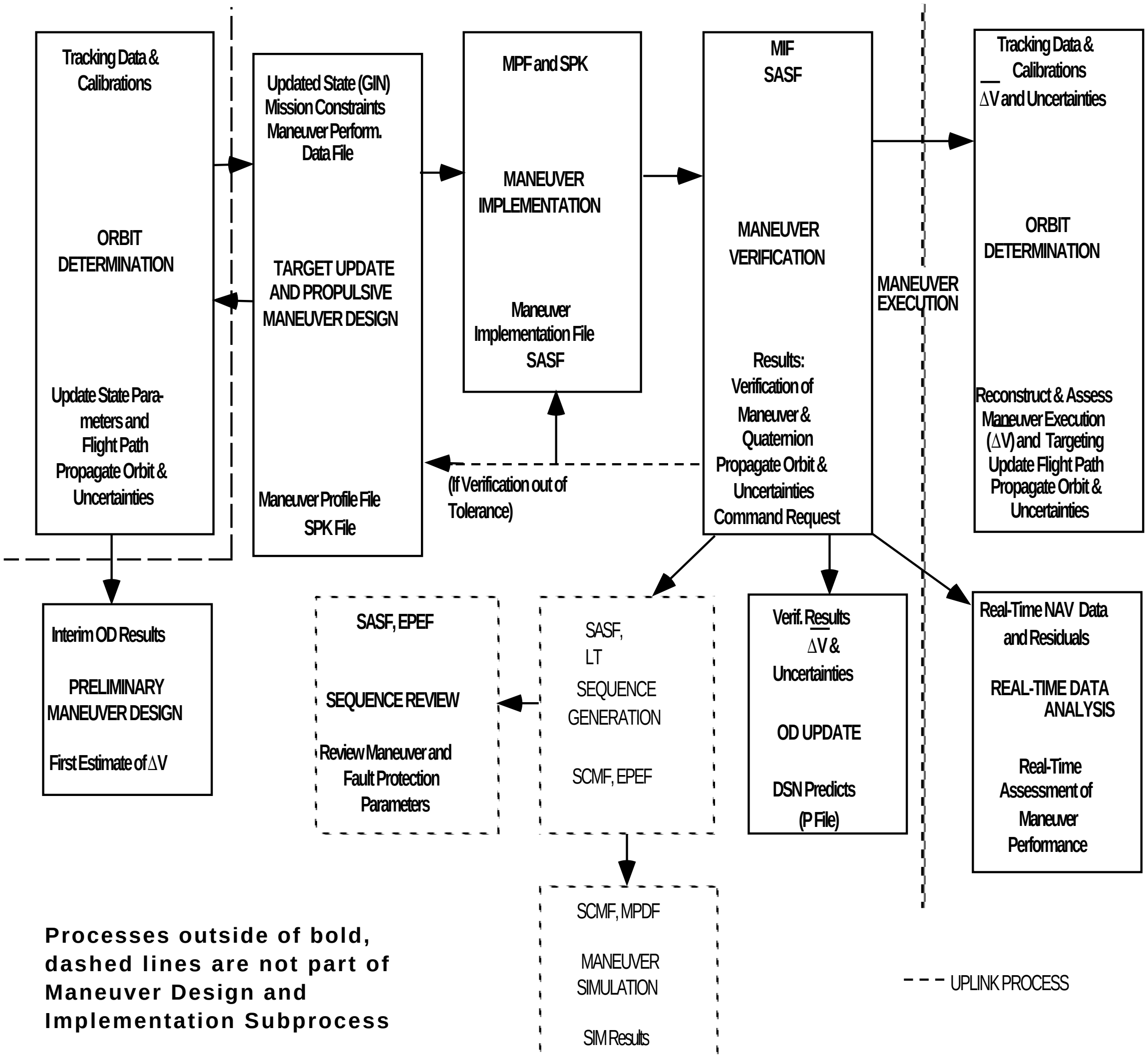


Figure 2-12

Process Flow for the Maneuver Design & Implementation Subprocess

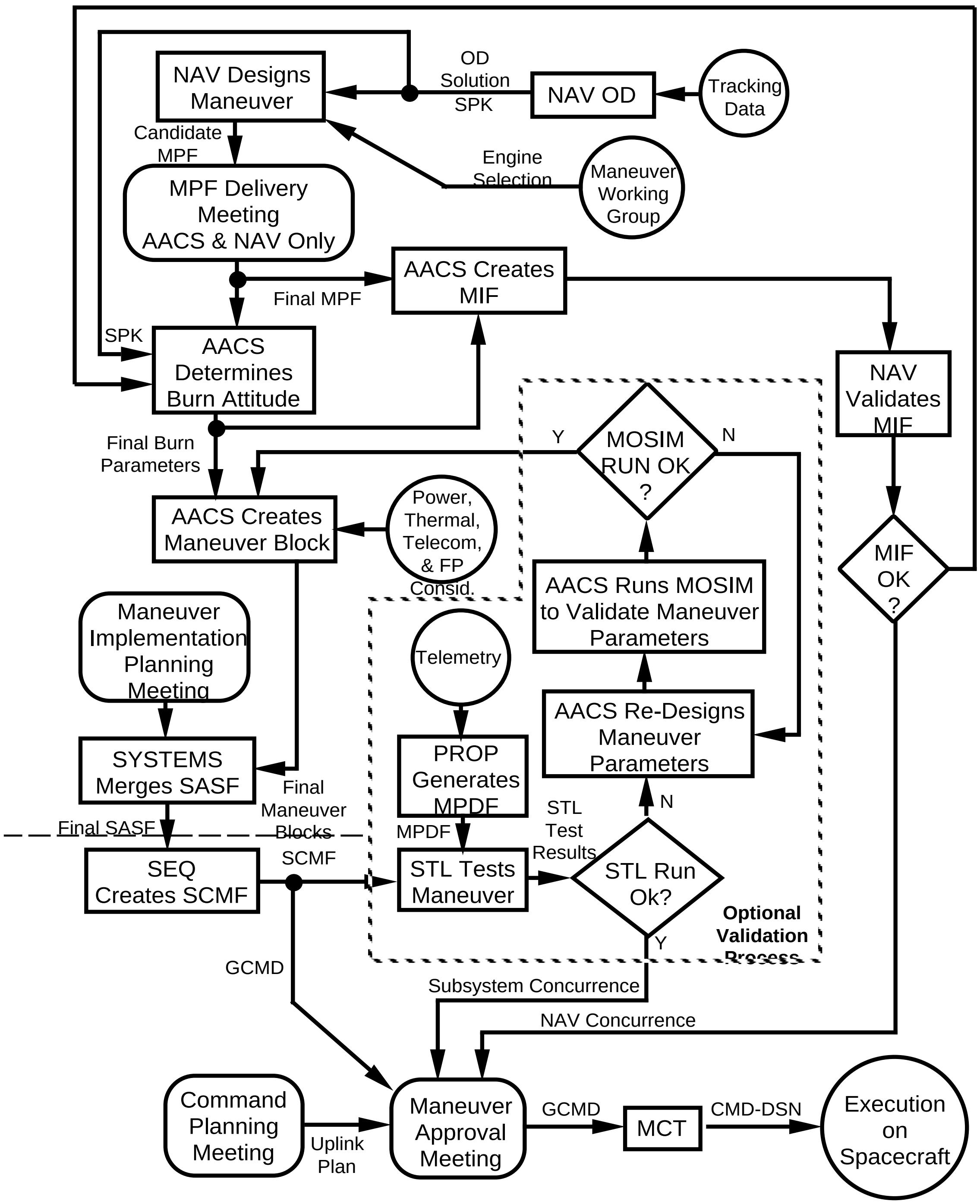


Figure 2-13

2.2.4 Flight Software Maintenance

Flight software maintenance is the subprocess of the downlink process responsible for the post launch upkeep of the flight software. It includes maintaining a known image of the flight software (FSW) on the ground, identifying and approving required changes to the FSW, and implementing those changes onboard the spacecraft.

This subprocess gathers all requirements for the proposed flight software change into a formal change request, performs the flight software design and coding, develops specific test requirements for validation, prepares the uplink plan for the change, and provides support for sequencing and uploading the modified software. Figure 2-14 pictorially illustrates the subprocess.

2.2.4.1 Flight Software Maintenance

Flight software maintenance is responsible for maintaining an accurate image of the spacecraft flight software on the ground. It is also responsible for the prediction of the flight software state resulting from commands executed on the spacecraft. It provides Mission Operations Assurance the configuration control version of the flight software.

The inputs required for this activity are the predicted flight software state for comparison to the actual flight software state, sequence products for commanded state changes, and PDB data containing memory readouts and state information. The output is a known memory image of the onboard flight software at any time.

2.2.4.2 Flight Software Change Identification and Approval

In order to efficiently achieve mission objectives, it is recognized that flight software changes are likely. These changes could range from simple patches to partial rebuilds, and their rationales are dependent on circumstances at the time. Once the need for a FSW change is identified, a comprehensive change request package is prepared for submittal to the project change board. This package will include the functional requirements, a design satisfying those requirements, the STL test requirements with specific cases to be tested, and an uplink plan. This package is submitted to the project change board for approval.

The inputs required for this process are the Mission Plan to provide a high level schedule of spacecraft activities, requirements from subsystems, sequence products (e.g., SOE and PEF), the current flight software image, and PDB data. The output is an approved change request for implementation.

2.2.4.3 Flight Software Implementation

Flight software implementation is responsible for accomplishing approved changes, including testing and uploading to the spacecraft. Using the design developed for the change request package, software code is written to satisfy the requirements. If it is determined during coding or testing that the design requires minor modifications from the change request baseline, delta approval from the change board is not necessary. If major modifications are required, significantly changing the approach or substantially increasing the scope of effort, a delta approval from the change board is required.

There are typically two types of STL testing conducted in support of FSW changes. The first type is performed using informal test cases to prove concepts and test the code functionality. The second type of testing is the normal STL testing to verify the upload with the actual SCMFs / GCMDs for formal command approval. Acceptance tests are performed using the specific test cases as provided in the change request to establish the new baseline for formal delivery.

Upon acceptance test completion, the validated software enters the standard uplink process for transmission to the spacecraft. The new baseline is provided to the MOA Team for configuration control.

The inputs required for this process are the approved change request, PDB data, and the current flight software state. The outputs are the new software and associated documentation.

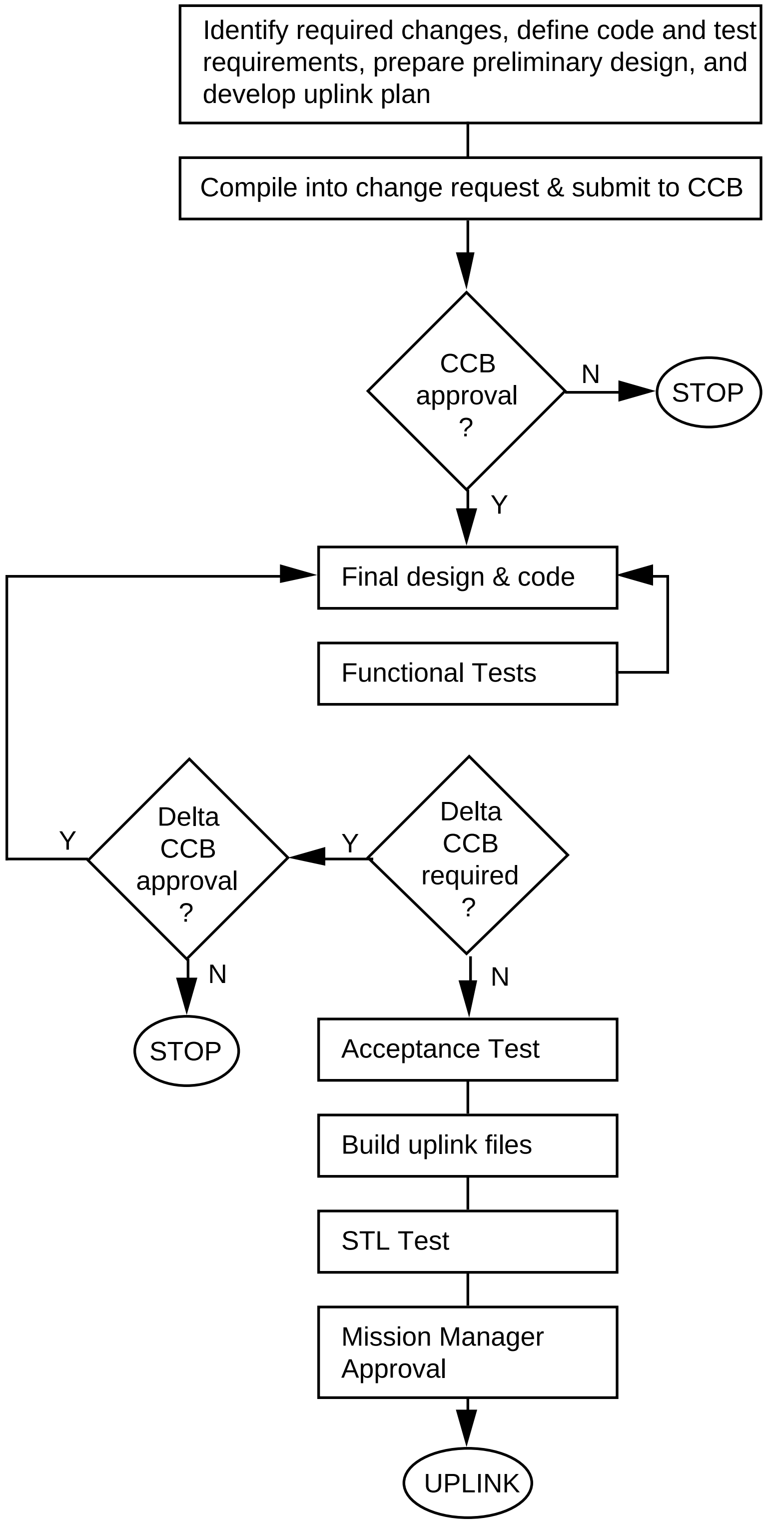


Figure 2-14. Flight Software Change Implementation

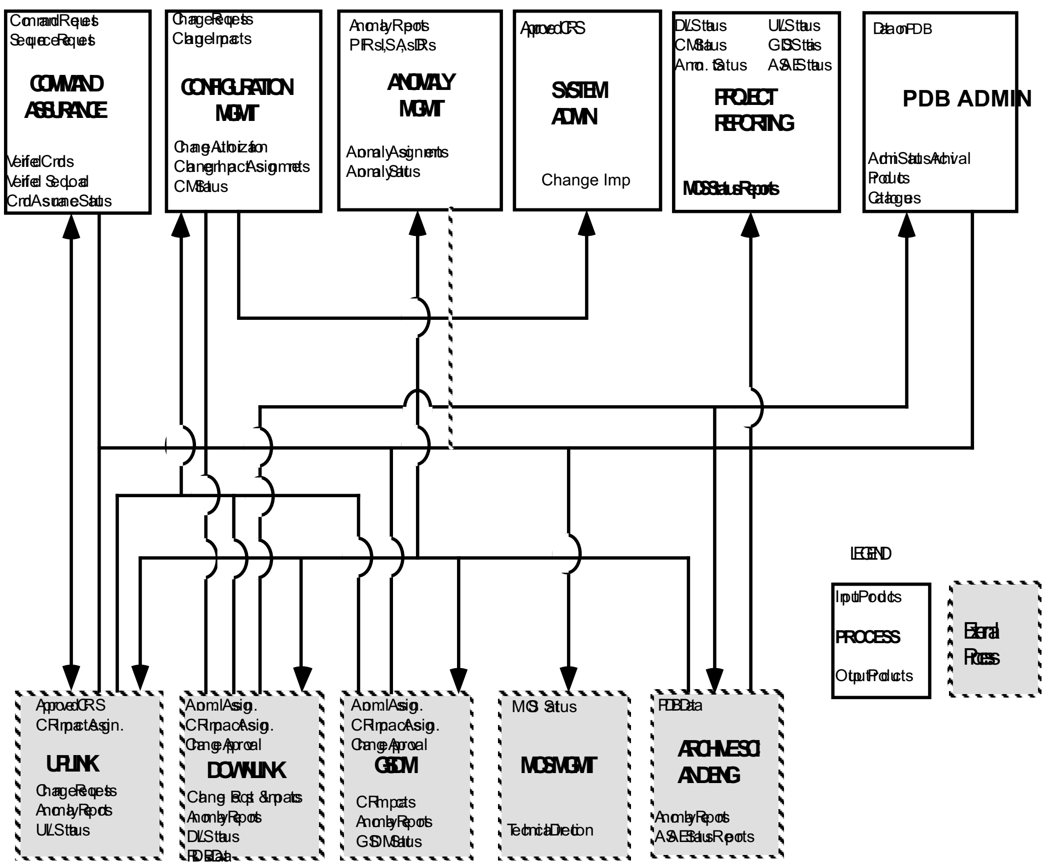
2.3 ARCHIVE OF SCIENCE AND ENGINEERING DATA

Refer to the following documents for information pertaining to this section:

Science Data Management Plan (542-310)
Project Data Management Plan (542-403)
Configuration Management Plan (542-412)

2.4 MISSION OPERATIONS ASSURANCE PROCESS

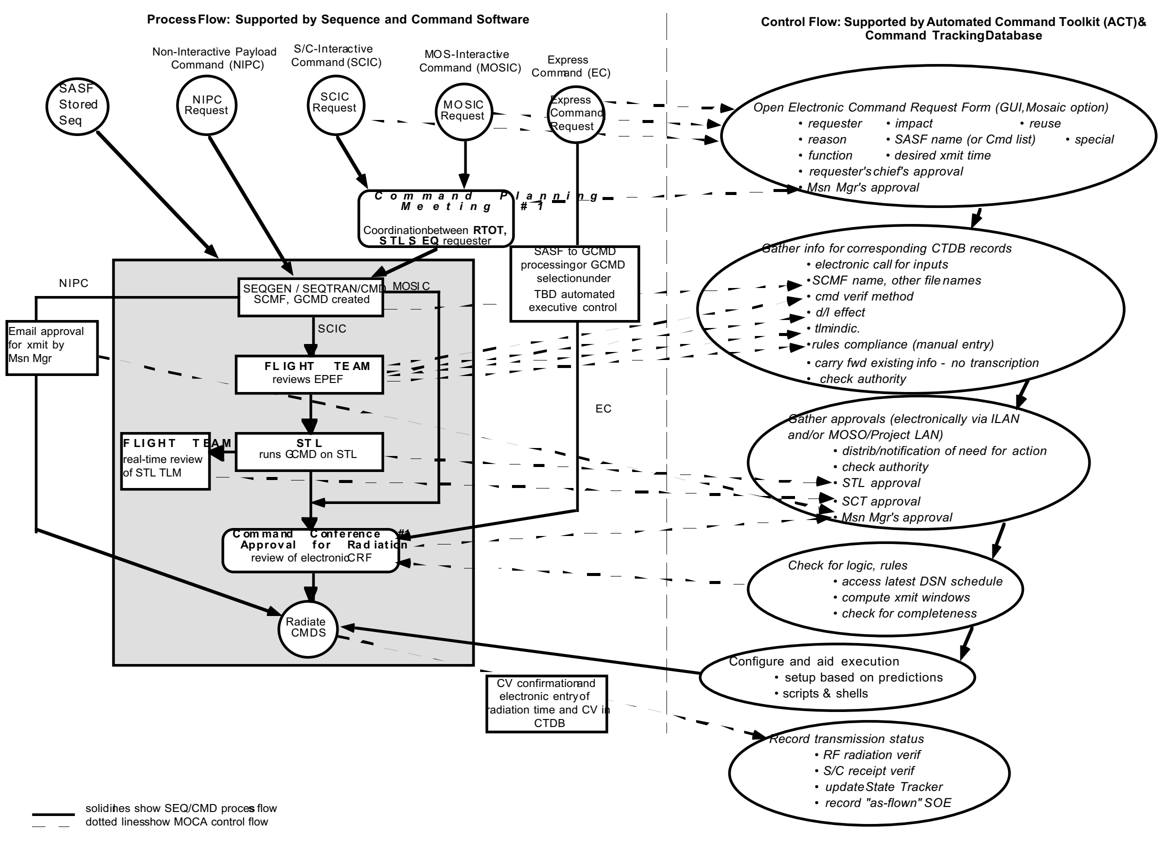
The Mission Operations Assurance Process shall process and monitor changes, failures, anomalies as they relate to hardware, software, documentation and operations. A MOA sub-process will also streamline the Project Reporting effort.
Maintaining the project database and data integrity also fall under the purview of MOA. There are has six subprocesses: Command Assurance, Configuration Management, Anomaly Management, System Administration, Project Reporting and Project Database Administration. See Figure 2-15 for the MOA Process Map.



MOA Process Map
Figure 2-15

2.4.1 COMMAND ASSURANCE PROCESS

The command assurance process insures that commands sent to the spacecraft are constraint checked, do not violate the flight and mission rules, are verified and validated to ensure that no erroneous commands are sent to the spacecraft that could a cause catastrophic failure. This is accomplished through constraint and rules checking (in the Sequence Team SEQ_GEN software), flight team reviews (using the sequence review tool), simulation of the sequence/commands through the Spacecraft Test Laboratory for validation, and use of the Command Tracking Data Base (CTDB) which verifies the command file to be sent is the correct one, and provides a command transmission history. (See Figure 2-16 for the CTDB operations.) When commanding errors are found in the flight team review, it is the responsibility of the SIE to add to the list of automatic checks using the SEQ Review tool. The Command Assurance process also supports the command conference where commands are approved for transmission. The command assurance process is a distributed process. See Figure 2-16 for the Command Assurance Process.



Command Assurance Process
Figure 2-16

2.4.2 ANOMALY MANAGEMENT

The Anomaly Management Process (see Figure 2-17) is the mechanism used for submitting, tracking and closing anomalies, failures or surprises during mission operations. The Anomaly Management Process accepts electronic Anomaly Reports in the form of Failure Reports, Discrepancy Reports, and Incident Surprise Anomaly Reports. The report is checked for sufficient information to enter into the database. Once the report has passed, its screened for content completion and is categorized, prioritized and assigned to a the appropriate team for impact and analysis. Closeout authority is also established here. An anomaly representative or will perform these tasks. The database tracks all movement of the report and gives an electronic reminder when there has been no action for a pre-determined length of time. Analysis is performed for resolution to the problem. Solution approval is given at the appropriate level based upon the established closeout authority and closeout notification is sent out.

Some anomaly reports will be archived for information only, to reduce the workload and enable the important anomaly reports to be solved. This is due to limited staffing in this area. The Anomaly Management process will also allow the originator to close out a report without completing the entire process if so deemed by the originator (i.e. a simple solution was found, or the reason for writing the anomaly report was invalid).

The Problem Failure Reporting System is institutionally supported. The PFOC system will accept MGSO Failure Reports and monitor them through cycle completion (although MGSO has its own system). These MGSO FRs will be downloaded from the MGSO reporting system to PFOC daily. The PFOC system will also interface with the DSN for electronic Discrepancy Reports.

The PFOC database provides electronic Anomaly reporting when requested or on a regular pre-determined basis.

2.4.3 CONFIGURATION MANAGEMENT (CM) PROCESS

The Configuration Management Subprocess to the Mission Operations Assurance Process is a formalized process for establishing baseline configuration and controlling changes to the configuration by stringent standards, for a tested and accepted ground data system (GDS), hardware and software; the overall configuration of the GDS, the MOS documentation and the flight software, including the routinely uplinked stored sequence scripts.

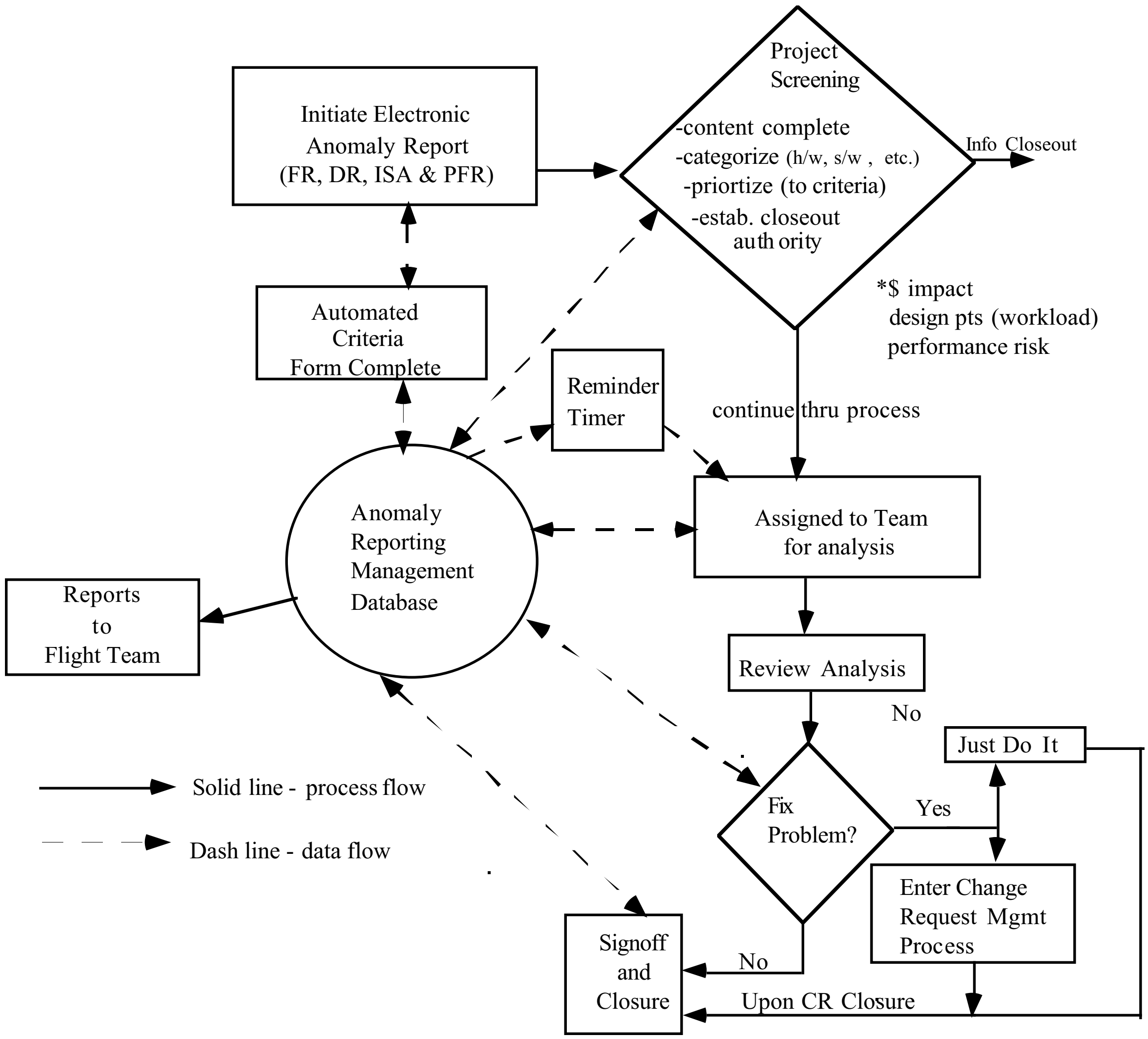
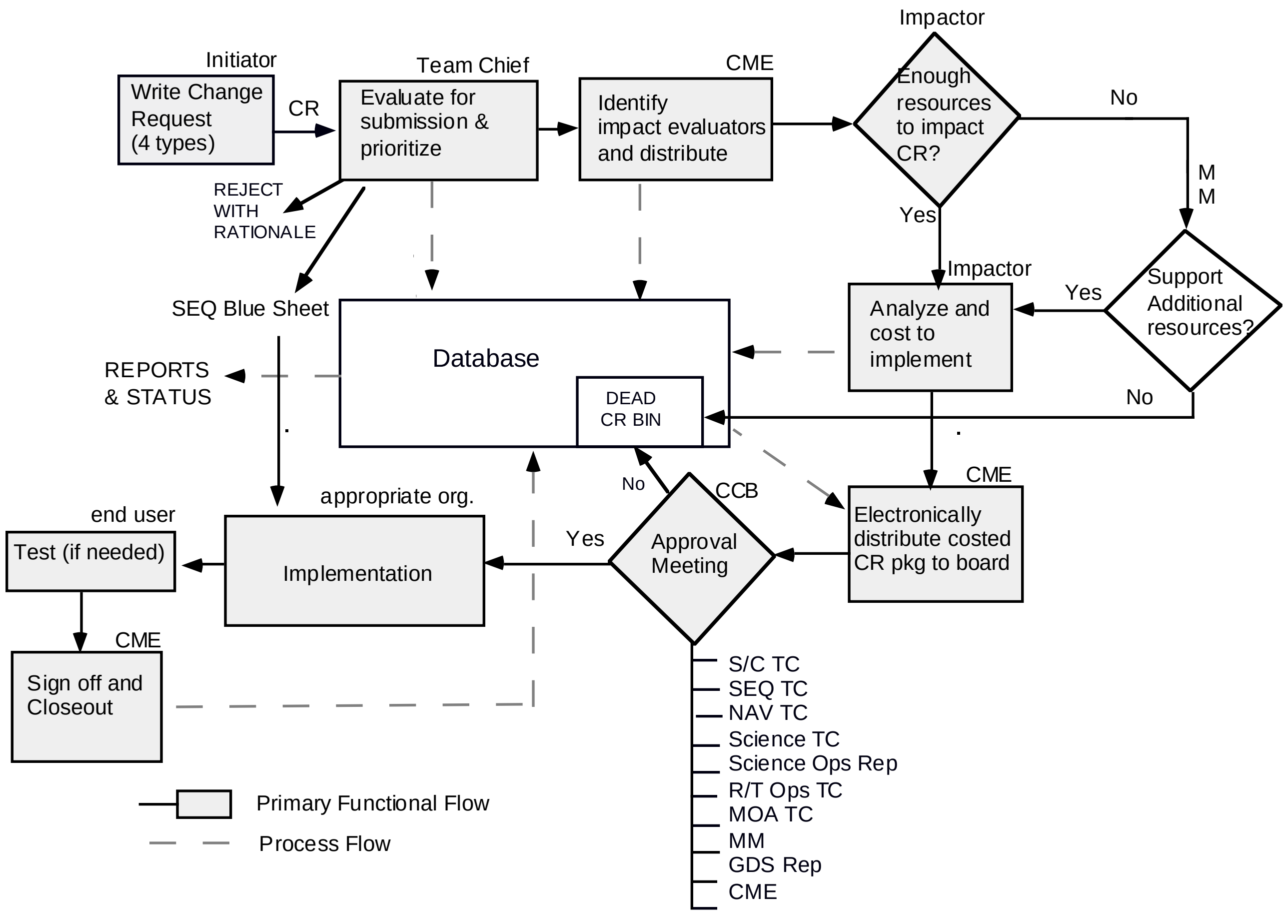


Figure 2-17
Anomaly Management

Two subprocesses of the Configuration Management are the Configuration Management Administration (CMA) and the Change Request Approval (CRA) subprocesses. The CMA establishes the criteria for level of control to be levied on the various products of the MOS. From this criteria, each MOS product's configuration controlled level is determined and an overall MOS baseline configuration is established. The control criteria is described in the MGS Mission System Configuration Management Plan, 542-412.
Inputs to this process are GDS deliverables, updated documentation, approved change requests. Outputs of the CM process are archive products and archive reports.

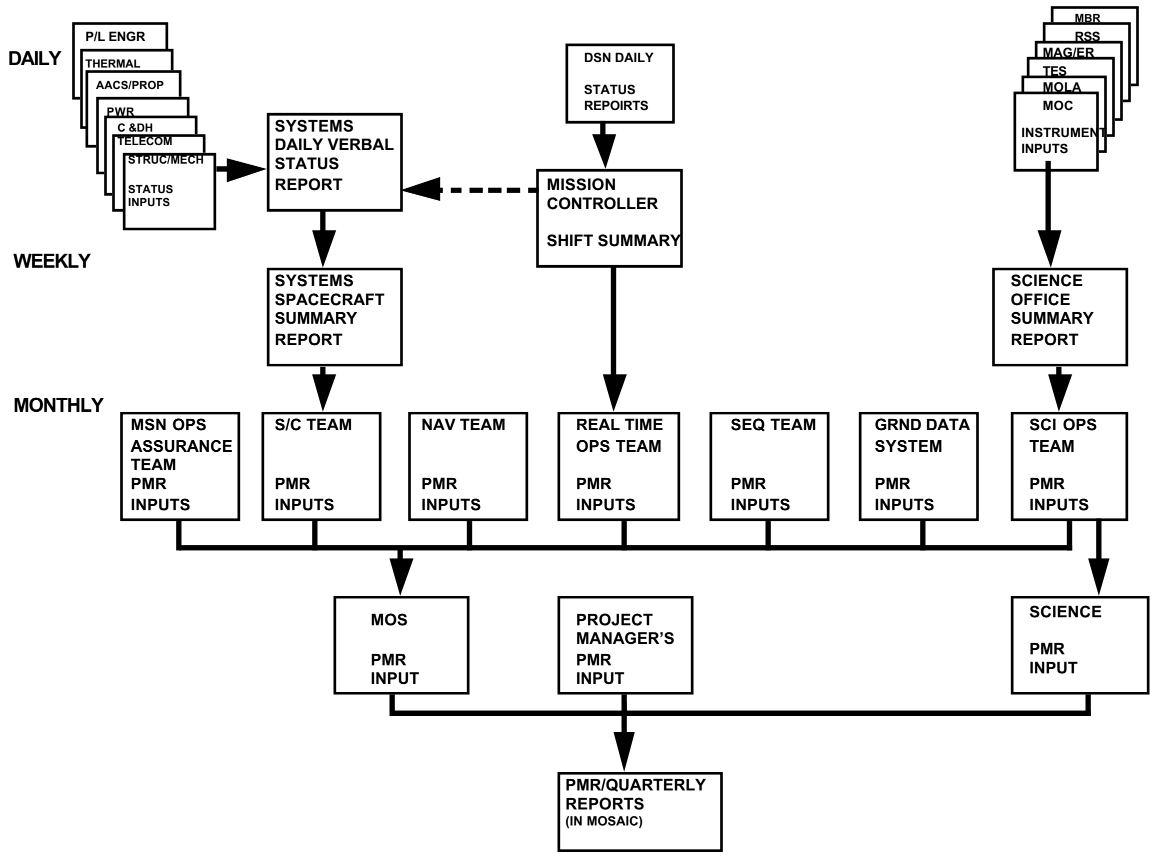
Figure 2-18
MGS Change Request Management Process



Throughout the mission it is expected that a number of problems could arise or changes desired to modify the baseline configuration. Desired changes to the baseline shall be identified through the initiation of change requests (CR). The CRA subprocess is the means of getting the proposed changes identified, properly evaluated, approved and implemented whether it affects MOS documentation, the GDS configuration, the MOS hardware and software tools or the flight software. The CRA establishes the required level of approval, i.e. at the individual, team, mission manager, or project managers levels, for changes again based on cost, risk and mission criticality. Approved or rejected CR's are outputs of the CRA activity and are sent to the affected users and implementers of the CR's. The Change Request Process is shown in Figure 2-18 above.

2.4.4 PROJECT REPORTING

The Project Reporting Process shall provide an easy electronic means for flowing information through the project. See Figure 2-19 for the process map.
The monthly reporting scheme is one where the appropriate team writes their input and submits it to the next reporting level (via the server). Each level



Project Reporting
Figure 2-19

summarizes the important points and passes the information forward until the Mission Manager has the appropriate level of data to submit to NASA for status.

The Project Monthly Report (PMR) and Monthly Management Report (MMR) will reside in MOSAIC for all to access. All documentation for operations will be accessible electronically. Paper copies will be supplied when appropriate.

2.4.5 SYSTEM ADMINISTRATION PROCESS

The System Administration Process shall be supported by MGSO personnel, dedicated to the MGS Project. System Administration shall provide the mechanism to ensure that high level security interfaces between the MGS Project and MGSO are effectively maintained. These interfaces will be carried out in accordance with the TMOD IOM (RP-May 1995-Rev.A) and the Mission Security Plan (542-404). Additionally, the System Administrator shall provide configuration control for all MGSO/AMMOS Ground Data System (GDS) elements necessary to support the MGS Project. The System Administrator shall install new MGSO software deliveries and solve connectivity/access problems, as required on all workstations.

2.4.6 PROJECT DATABASE (PDB) ADMINISTRATION PROCESS

The Project Database Administration Process shall provide off-line coordination and analysis of Project Database operations. PDB Administration shall ensure that all project electronic data are maintained in the Project Database (PDB) and that new data is backed up on a daily basis. The PDB Administrator shall be responsible for all PDB operations, including data storage, data retrieval, data transfer and maintenance. When necessary, the PDB Administrator shall convert the data from one storage medium to another, in order to satisfy storage and transfer requirements. In addition, the PDB Administration shall develop and implement the procedures necessary to allocate database access privileges and maintain MGS PDB security policies.

2.4.7 DATA ARCHIVAL PROCESS

The Data Archival Process shall ensure that all electronic data products are archived, on a daily basis, in coordination with the PDB Administrator. The Data Archive Process will work closely with the PDB Administration Process, ensuring that all new raw science and engineering data are archived to the Planetary Data System (PDS).

2.4.8 E-KERNEL GENERATION PROCESS

The E-KERNEL Generation Process shall provide an easy electronic repository for storing all Mission Operations information, for archival purposes and lessons learned. The E-KERNEL shall provide the necessary means for reconstructing any time/date or scenario for ease of locating applicable information, such as a specific time frame for future analysis. It will be located in the PDS and will incorporate all electronic information from applicable email, to Mission sequences, timelines and scenarios.

2.4.9 TRAINING PROCESS

The Training Process shall ensure that Flight Team members are adequately trained and ready to support major Mission events, particularly Launch, MOI and Aerobraking. The Training Engineer shall be responsible for establishing and scheduling various Test and Training activities as to exercise the entire flight team and evaluate operations readiness prior to major Mission milestones. Following each exercise the training engineer shall assess Flight Team readiness by holding test debriefings and documenting lessons learned.

SECTION 3

ORGANIZATION

3.0 MARS GLOBAL SURVEYOR MOS FLIGHT TEAM ORGANIZATION

The MOS Flight Team consists of the following teams:

a. Spacecraft Team (SCT)
b. Science Operations Team (SOT)
c. Navigation Team (NAV)
d. Sequence Team (SEQ)
e. Mission Operations Assurance Team (MOA)
f. Real-Time Operations Team (RTOT)
g. Mission Management (includes mission planning, resource scheduling, etc.)

The MOS Flight Team is lead by the Mission Manager.

The organization of the MGS Mission Operations System Flight Team is shown in Figure 3-0.

The functional responsibilities of the operations teams of the MOS are listed below.

3.1 Real-Time Operations Team

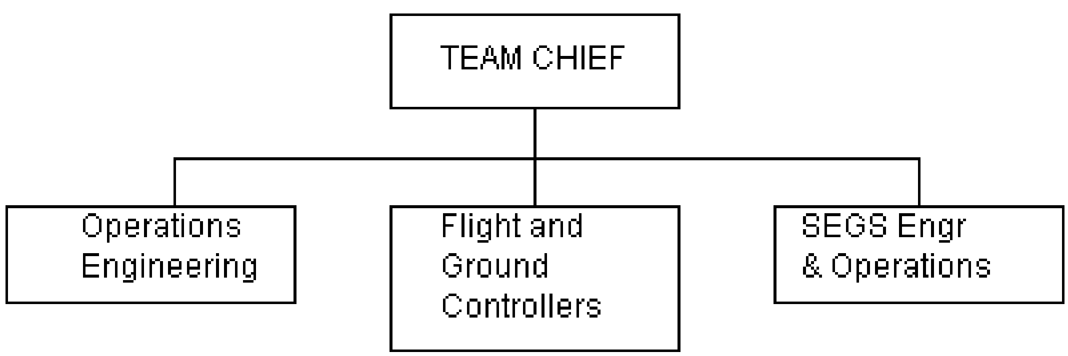


Figure 3-1: Real-Time Operations Team Organization

Figure 3-1 shows the Real-Time Operations Teams organizational architecture. The Real-Time Operations Team (RTOT) is responsible for the functions, processes and services associated with Deep Space Network Operations, the Data Sytems Operations, Mission Control and SEGS operations. The RTOT straddles the reengineered uplink and downlink processes.

Mission Operation Organization

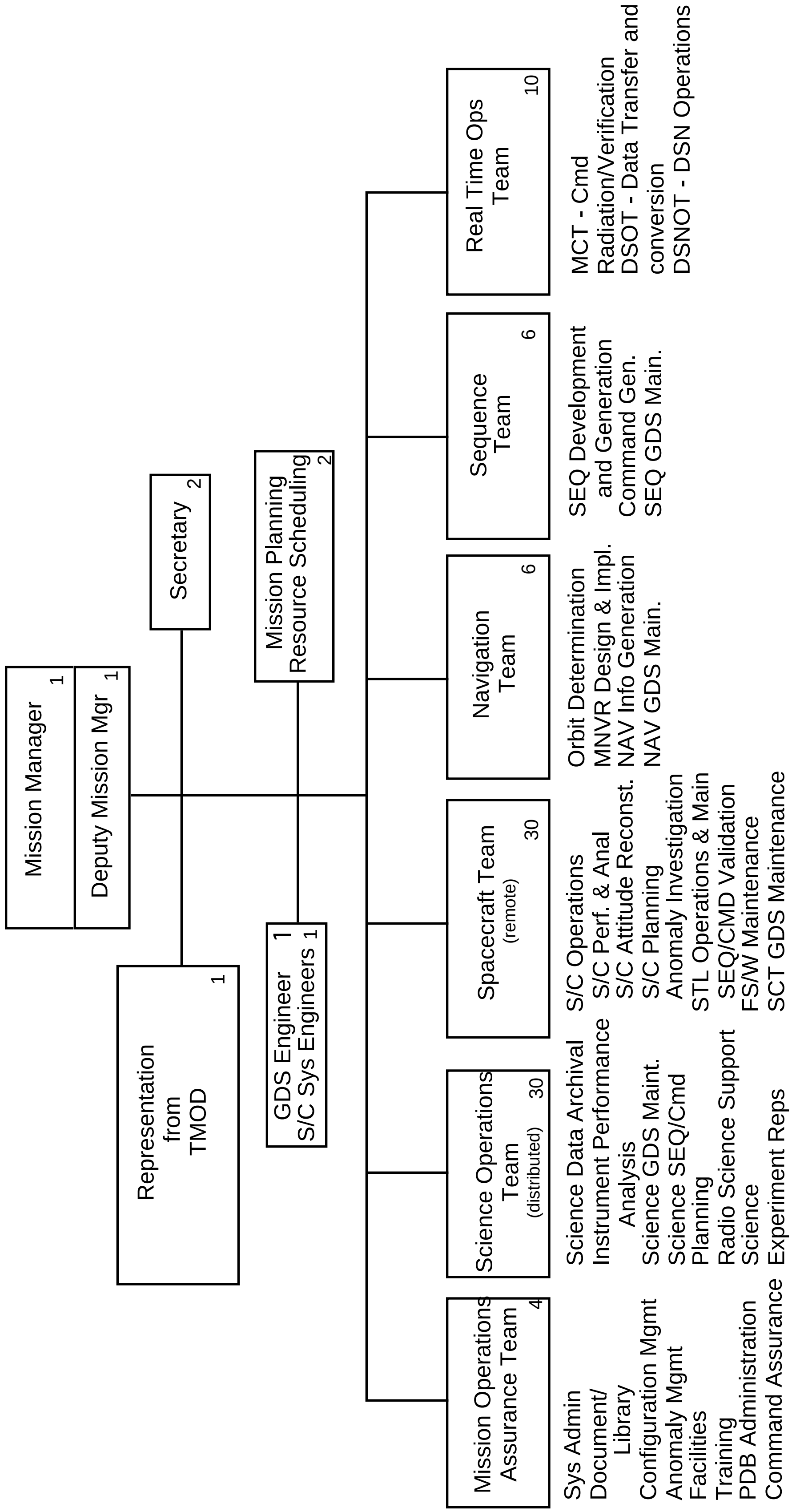


Figure 3-0

The Real-Time Operations Team consists of:

1. Team Chief
2. Flight Operations Engineering
3. Mission Controllers
4. SEGS Engineering and Operations
5. DSOT Operations
6. DSN Operations

The Team Chief is responsible for the (cross-)training, operations and cognizance of the Real-Time Operations Team. The Team Chief reports to the Mission Manager.

Flight Operations Engineers design, develop, test and integrate enabling technology into the RTOT Procedures and practices. They are aware of and forecast the implications of TMOD (DSN and MGSO) and Mars Exploration Program (MEP) Office developments and operations.   They represent and are expert in operational considerations at Project Planning meetings. They propagate the results of Project plans and decisions to the real-time community.

Mission Controllers perform Ground System Monitor, Control and Configuration processes. They are also spacecraft and mission knowledgeable. They have the responsibility for the execution of mission plans and the security and integrity of its processes and products in real-time. The Mission Controller is a stakeholder, Project spokesman, in the highly contentious real-time arena.

SEGS Engineering and Operations inputs uplink process predicts and outputs electronic files which will be used as traditional products (SFOS, SOE, and DSN Keyword files) or as data used for systems configuration and process automation tools which dynamically model predict data for computer aided data reduction and presentation.

DSOT Operations provide the data aquisition functions as defined in the “Multimission Ground Data Sytem Operations” document, number 2000-5-3050, Rev.D.

DSN Operations are defined in the “Network Operations Plan (NOP)” 870-333.

3.1.1 PROCESSES

3.1.1.1 Real-Time Operations Team

The Real-Time Operations Team is derived directly from MGS MOS Reengineering and traces back to their derived Process Maps. The RTOT inputs negotiated resource components, predict-sets and telemetry. The RTOT outputs time-ordered, best-available data sets, analysis and reports.

Pursuant to the RTOT process reengineering map, figure 3-2, the RTOT shall:

1.Configure allocated multimission real-time ground data system elements into a calibrated, MGS activity-specific string.

2.Detect, characterize and act upon incidents, surprises and anomalies which may occur during spacecraft tracking sessions.

3.Collect, normalize and integrate predict information for the Flight Team. It shall provide documents and data sets for the Flight Teams to use to coordinate flight activities and plans.

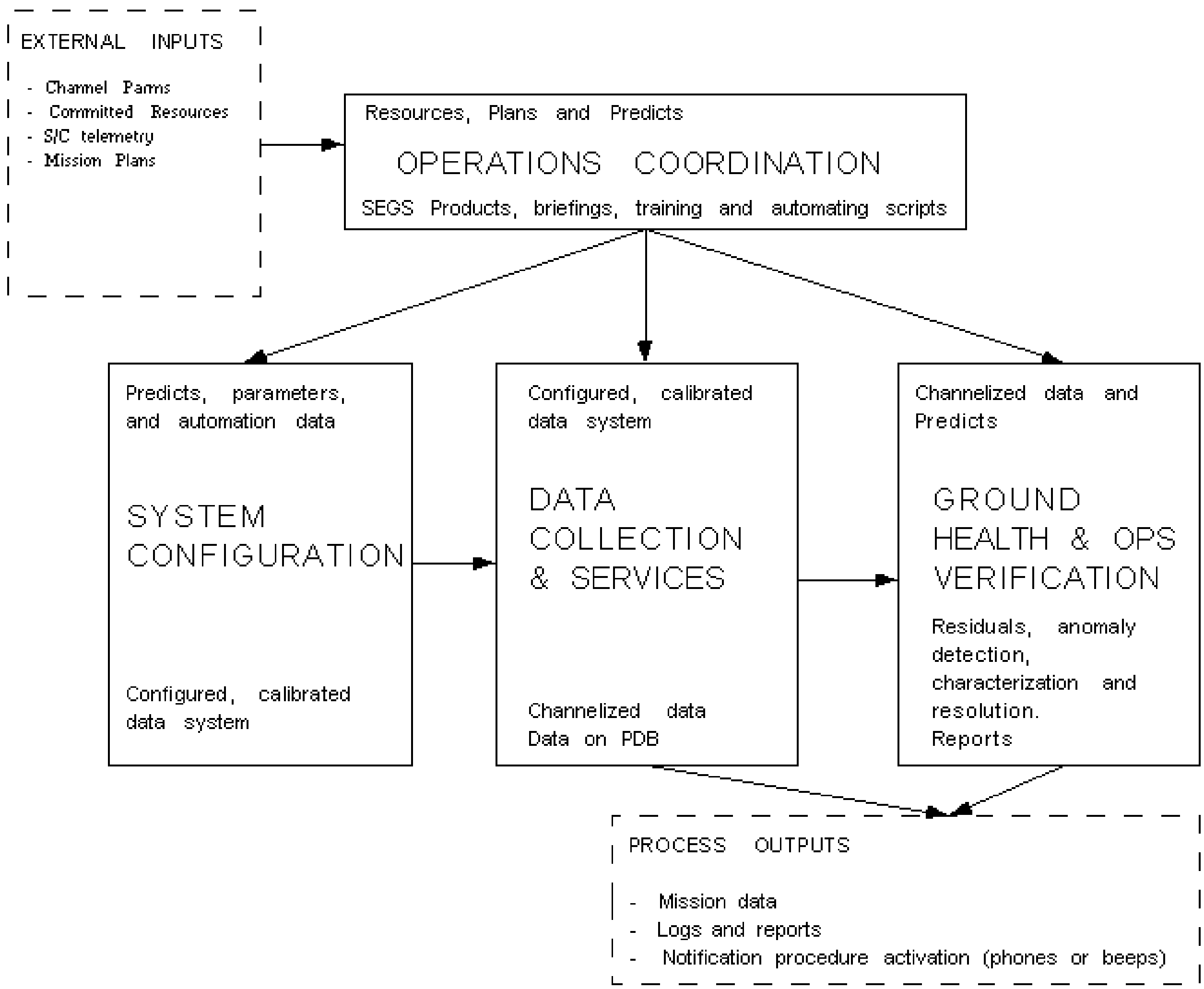


Figure 3-2: Real-Time Operations Team Processes

	Pre Real-Time	Real-Time	Post Real-Time
Team Chief	Training Documentation Team Coordination	On-call for anomaly resolution SEGS Backup	Reports Team perf. ass'm't
Ops Engr	Operations Plans Tools Development Ops Coordination Ad Hoc Studies Mission Sys. Mtgs.	Mission contoller Backup	Ops Analysis - trends - problems - cont. improve. Cmd Post Processing
Mission Controllers	Config GDS Calibrate GDS Validate GDS	Commanding & CV EEIS QQC Predicts vs Actuals Anomaly Detection	Data gap fills Anomaly Reporting Cmd Req closeouts Controller logs
SEGS Engr & Ops	Input Predicts Output Predicts - normalized - time ordered - automation	Team Backup as required and certified	SPICE E-Kernel - "as-flown" SOE

Table 3.1.2: Real-Time Operations Team
Functions by Position

3.1.2 OPERATING PLANS FOR THE REAL-TIME OPERATIONS TEAM

Table 3.1.2 encapsulates the major functions of the RTOT during pre-real-time, real-time and post-real-time.

3.1.2.1 Pre-Real-Time Activities

1.   Ensure team procedures, interface agreements and other documents are generated and maintained.

2.   Design team workstation tools, display sets and default set-ups.

3. Operations Engineers are members of uplink planning teams. They participate in process discussions and turn decisions into executable operations plans. They enable Real-Time processes which result in scripts, briefings, predict data sets, tools and interaction as required.

4. SEGS Engineering and Operations are responsible for mission specific adaptations and the continuous improvement of SEGS.

5. Prior to each tracking session with the spacecraft, the RTOT shall configure, precalibrate and validate the GDS string for both uplink and downlink operations per the SOE and DSN Keyword File (DKF).

6. Ensure the real-time community has the products and information to perform the necessary operations. This includes predicts, briefings, documents, files, forms, checklists, tools, operational margins, operations and contingency plans, and special advisories.

3.1.2.2 Pre-Real-Time Data Systems Configuration

Baseline and situation-specific data system configurations are defined by the SEGS SOE and DKF; SCT engineering data; SOT community requirements; and operational considerations.

SEGS outputs are transformed into time-sensitive data system syntax files to automate operations.

3.1.2.3 Real-Time Activities

<u>Real-Time Uplink Operations</u>

In real-time, the RTOT shall radiate authorized commands in accordance with Mission policies, procedures, protocol, special instructions and constraints.

In order to facilitate commanding, the Mission Controller is provided with an uplink plan summary, on-line electronic command request forms, data system status displays and procedures designed to minimize errors and maximize throughput.

Transcription and timing errors are minimized by ECRF - CMD interface automating scripts..

Command files are forwarded to the transmitting station as early as practical in order to maintain commandability in case of local systems failures.

Information that the data system “knows” such as bit-one radiation times, RTLT CV times, and station status (e.g. command mod on/off) do not have to be manually transcribed from the screen to a form or keyboard.

Procedurally, most Sequence Team generated CMD_DSN/GCMDs are indistinguishable. Console commands are slightly different.

In the case of console commands, a CMD_DSN/GCMD is not provided -- only an authorized ECRF. Transcription errors are again minimized by electronic connectivity between the ECRF and CMD subsystem to elminimate transcription errors. This is particularly critical in the case of console commands because of the complexity of manually transcribing commands which contain mnemonics, large numbers of comma delimited arguments and command system pecularities such as using hyphens as line continuation characters

Real-Time Downlink Operations

Once data is flowing through the End-to-End Information System, Mission Controllers are responsible for maintaining all parameters within prespecified limits. When parameters go out of limits, it is the real-time communities responsibility to detect, characterize and reconcile the discrepancy.

Parameters may be spacecraft engineering channels, GDS measurements or settings.

Post-Real-Time Activities

Operations Analysis

Post-real-time operations analysis performs uplink-downlink closure. Incidents, surprises, anomalies and problems which are not fully resolved in real-time are researched and resolved after the fact. This analysis includes at least the following.

a. ad hoc studies and requests
b. trend analysis
c. continuous improvement
d. open ISAs, DRs, FRs as required
e. ISA analysis and closure

Command Post-Processing

The Electronic Command Request system provides the following data and reports for Operations Engineering and the Project.

a. command activity results and summaries
b. command anomaly research and analysis
c. ad hoc studies and requests

3.2 SPACECRAFT TEAM

The Spacecraft Team (SCT) shall be responsible for operating and maintaining the MGS spacecraft. In carrying out this responsibility, the Spacecraft Team shall:

1. Plan future spacecraft activities and support the mission planning and sequencing activities.

2. Predict future spacecraft performance.

3. Analyze spacecraft telemetry and ground data to determine spacecraft performance using the special purpose computer programs of the Engineering Analysis Element (EAE).

4. Develop engineering objectives.

5. Operate the spacecraft in realtime and non-realtime, including implementing maneuvers and operating the spacecraft during anomalous conditions or recovery therefrom.

6. Report on the health and status of spacecraft subsystems.

7. Maintain the ground software supporting spacecraft operations.

8. Maintain spacecraft telemetry decom, decal and alarm limits database files.

9. Archive selected processed engineering data.

The SCT will nominally operate five 8-hour days per week in Denver. During high activity periods, including but not limited to launch, TCMs, OTMs, MOI, aerobraking and anomaly recoveries, the SCT will operate at a level commensurate with the needs of the Project, including extended shifts or weekends when necessary. The SCT will exist as an operational entity from the beginning of formal Flight Team test and training activities through the end of mission. The SCT Chief, the two group leads, and selected additional senior team members will provide a rotating non-continuous presence at JPL throughout the mission for coordination and liaison purposes. During launch operations, the SCT will coordinate with the launch team and respond to requests for telemetry analysis and commands as appropriate.

As shown in Figure 3-3, the Spacecraft Team consists of the team leadership plus two functional groups: Systems and Subsystems. The top level responsibilities of these elements are as follows:

1. Leadership: Responsible for overall Spacecraft Team Operations and interfaces with the Flight Team and external elements.

2. Systems: Responsible for overall coordination of operational activities, as well as STL operations and the Mission Support Area (MSA).

3. Subsystems: Responsible for subsystem performance, maintenance, analysis, prediction, and status and health reporting.

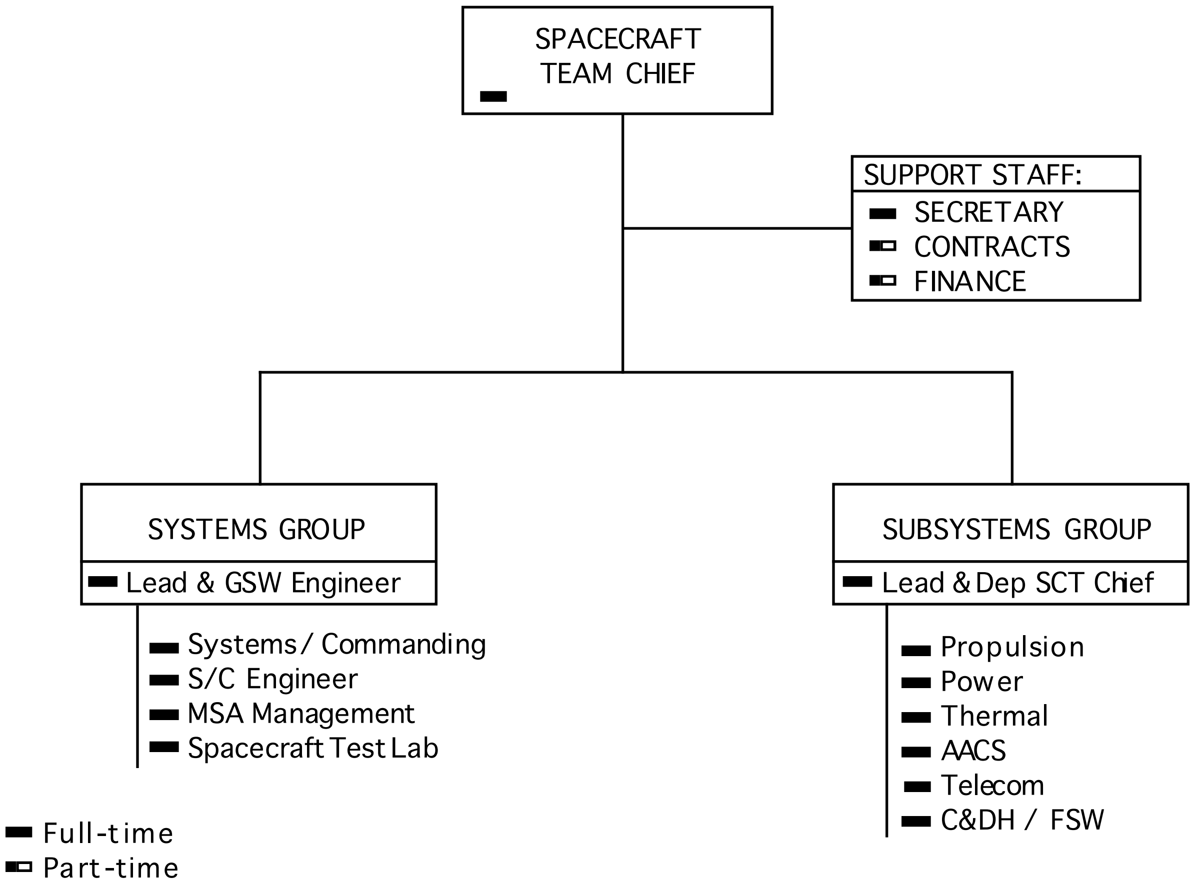


Figure 3-3. Spacecraft Team Functional Organization

The essential functions of the team leadership and the two groups are described in the following sections.

3.2.1 Team Leadership

SCT leadership consists of the SCT Chief and a Deputy Team Chief (also the Subsystems group lead). The Team Chief reports to the Mission Manager. The functions of SCT leadership are as follows:

1. Schedule team activities and establish priorities.

2. Monitor team progress, provide direction, and take corrective action whenever required.

3. Provide program status to Lockheed Martin management.

4. Provide team status, spacecraft subsystems' status, and resource requests to the Mission Manager.

5. Support mission planning meetings, sequence approval meetings, and others as required. Conduct periodic spacecraft status meeting.

6. Provide primary interface with other flight teams.

7. Approve selected team products and outputs to other teams.

3.2.2 Systems Group

This element of the SCT provides Systems Engineering support, ground software maintenance support, flight software and sequence checkout in the Spacecraft Test Laboratory, Denver SCT MSA equipment management support and the Program Support Library to the Flight Team. The group lead will also serve as the Ground Software (GSW) Engineer. The functions necessary to achieve the objectives of this group are given below.

3.2.2.1 Systems Engineering

Systems Engineering, including the Spacecraft Engineer, is responsible for systems analysis, support of contingency planning, technical review of ground software changes, system level analysis coordination, maintenance of systems documentation, and support of on-line operations planning. The functions of Systems Engineering are as follows:

1. Provide systems-level and fault protection trade studies and analyses, including modifications to fault protection parameters.

2. Maintain systems-level documentation, including block dictionary and contingency plans. *[TELEMETRY AND COMMAND DICTIONARY MAINTENANCE IS ASSIGNED TO SUBSYSTEMS GROUP -- SEE C&DH ITEM #3]*

3. Coordinate Payload inputs to sequencing and interactive command processes.

4. Provide planning and coordination for SCT support to the RTOT.

5. Support SCT status meetings.

6. Coordinate, collect inputs, and produce daily (verbal) and weekly (emailed) SCT status reports.

7. Coordinate SCT requests for interactive commanding.

8. Coordinate procedure preparation and execution of procedures for multi-group tasks.

9. Coordinate collection of SCT inputs to the sequence generation process.

10. Review and approve sequence and interactive command products.

11. Provide systems support to STL operations.

12. Maintain current planning documentation in available form, including RTOT-produced SOE and SFOS.

13. Resolve SCT sequence conflicts; support resolution of all sequence conflicts.

14. Lead the aerobraking control functions of the SCT.

15. Maintain a historical record of uploaded commands in a command database.

3.2.2.2 Ground Software Support

This element of the Systems group is responsible for all software modifications to ground software used by the SCT, on an as-required basis. The functions of Software Support are as follows:

1. Write, submit and track Engineering Change Requests (ECR) for ground software as necessary to maintain operational capability.

2. Modify ground software as directed by approved ECRs.

3. Update appropriate ground software documentation to reflect implemented modifications, including Design Specification and User’s Guides.

4. Acceptance test new software deliveries, prepare appropriate documentation, and deliver to the program, as required.

5. Maintain SCT workstation software tools and databases, such as procedural scripts, informal analysis routines, Template Description Language (TDL), and Channel Conversion Language (CCL).

3.2.2.3 Mission Support Area (MSA) Management

This element is responsible for equipment configuration and maintenance in both the SCT MSA and the STL. The functions of MSA Management are as follows:

1. Interface with Lockheed Martin Facilities personnel for MSA support services.

2. Monitor and control configuration of all Lockheed Martin-provided equipment in the MSA and STL.

3. Interface with JPL to achieve configuration control of all JPL-provided equipment in the MSA and STL.

4. Institute repairs of Lockheed Martin-provided equipment in the MSA and STL.

5. Contact vendor maintenance service for repairs of JPL-provided equipment in the MSA and STL.

6. Maintain an inventory of all MSA and STL equipment, including repair history.

7. Provide system security for the MSA LAN.

8. Provide physical security for the MSA and STL.

9. Provide contingency data checkpointing and recovery capability on a regular, scheduled basis.

10. Collect, catalog and store the information and products necessary for the Spacecraft Team to conduct mission operations in a Program Support Library. This information may consist of documents, logbooks, test results, vendor drawings, computer tabular output, plots, tapes, floppy disks, etc.

11. Maintain and control access to the information and products contained in the Program Support Library.

12. Perform Configuration Management for all flight and ground software.

13. Maintain Release Description documents for all flight and ground software, following approved modifications.

14. Maintain configuration control of versions of commercial software packages on all computers in the MSA and STL.

3.2.2.4 Spacecraft Test Laboratory

The Spacecraft Test Laboratory (STL) provides the SCT with a capability for flight software modification verification, block validation, flight software parameter validation, sequence and command validation, and anomaly resolution. The functions of the STL are as follows:

1. Support flight software reprogramming and verification.

2. Validate newly-developed or modified stored or real-time command sequences using the STL, as appropriate.

3. Verify on-board parameter data which is modified through flight software loads or stored sequence changes.

4. Validate command block updates, as appropriate.

5. Support anomaly investigation and resolution.

3.2.3 Subsystems Group

The principal function of the Subsystems Group is to analyze and maintain the health and performance of spacecraft subsystems for both nominal and contingency operations. The group lead will act as Deputy SCT Chief. The functions of the individual subsystems are described below in general terms, followed by a list of the subsystem elements with specific functions applicable to each subsystem:

1. Define proper operation and maintenance requirements for the subsystem.

2. Define appropriate procedures for subsystem operations, including maintenance or calibrations, where applicable.

3. Define and maintain telemetry requirements for subsystem performance analysis.

4. Define and maintain alarm limits for the various mission phases.

5. Define and maintain appropriate workstation display configurations.

6. Perform periodic reports on the subsystem health and status, including status of consumables and predicted life of subsystems.

7. Perform periodic performance predictions, as required.

8. Perform subsystem performance analysis, particularly in cases of anomalous or unpredicted performance.

9. Produce input to the mission planning and sequencing processes and review mission planning and sequence products.

10. Support real-time operations, as required.

11. Define constraint checking requirements for the subsystem and ensure implementation of adequate and appropriate constraint checks in software or procedure checklists.

12. Monitor subsystem performance through evaluation of selected spacecraft telemetry to assess current status.

13. Analyze selected spacecraft telemetry to establish performance trends, including uncertainties.

14. Operate the subsystem analysis programs and maintain the models and databases of the EAE.

15. Generate and track subsystem-related engineering command and sequence activity requests.

16. Maintain a database containing the current and historical performance and

configuration status of the subsystems.

17. Support STL test planning, conduct, and analysis, as required.

The individual subsystem functions are as follows:

3.2.3.1 Propulsion

1. Support propulsive maneuver design by Navigation Team (NAV).

2. Compute required engine burn times based on predicted performance and required delta velocity.

3. Perform maneuver reconstruction using propulsion and other subsystem telemetry for each TCM, selected OTMs, and for MOI.

4. Estimate mass, moments of inertia, and center of gravity for planned and executed propulsion events and mechanism deployments.

3.2.3.2 Power

1. Determine spacecraft energy balance by monitoring amp-hours in versus amp-hours out.

2. Generate predicted power profile for selected sequences.

3. Generate actual power profile and compare it with predicted power profile previously generated.

3.2.3.3 Thermal

1. Generate predicted temperature profiles for selected sequences.

2. Generate actual temperature profiles from telemetry and compare with predicted profiles previously generated.

3. Maintain a spacecraft thermal characteristics database.

3.2.3.4 Attitude and Articulation Control (AACS)

1. Convert ephemerides in J2000 coordinates to the coordinates and format required by the spacecraft.

2. Predict Celestial Sensor Assembly (CSA) star crossings suitable to support attitude control by the CSA and generate the required commands for loading the star catalog.

3. Predict field of view constraint violations due to solar, planetary, satellite, and other identifiable sources during all phases of the mission.

4. Calibrate the AACS gyros through analysis of telemetry from a special uplinked sequence of spacecraft events.

5. Update star calibration gains as a function of the changing trajectory profile.

6. Compute and maintain attitude control gains.

7. Assess accelerometer accuracy.

8. Perform attitude reconstructions, as required.

9. Develop parameter inputs for maneuver design.

10. Perform maneuver reconstructions, as required.

11. Support science instrument calibrations.

12. Analyze telemetry from momentum wheel desaturations to determine effect on propellant mass and S/C velocity.

3.2.3.5 Telecommunications

1. Develop strategy for telecommunications reconfigurations associated with entry and exit from solar conjunction.

2. Generate predictions of spacecraft to DSN telecom link performance parameters required for planning and operations.

3. Evaluate telecom link performance and recommend subsystem mode changes to sequence design to assure optimum performance.

4. Provide signal level predictions and RF subsystem performance data.

5. Serve as technical interface between the SCT and the RTOT telecom analysis support personnel who will be responsible for real-time telecom link analysis.

6. Maintain the MGS Project telecom link database and maintain consistency with the DSN telecom link database used for MGS support.

3.2.3.6 Command and Data Handling (C&DH) and Flight Software (FSW)

1. Analyze memory readout telemetry and compare with ground maintained flight software memory maps.

2. Maintain knowledge of the response of the C&DH to commands (e.g., number

received, number rejected of each type). Maintain a record of command and data errors by time, error source, and type.

3. Generate and maintain decommutation maps, data number (DN) to engineering unit (EU) conversion algorithms, and default red alarm limits (as required) for all spacecraft telemetry, including the instruments. Maintain telemetry and command dictionary databases.

4. Perform regular analysis to correlate spacecraft event time to UTC. Produce and maintain the SCLK/SCET correlation file.

5. Provide programming and engineering support to facilitate reloading of new versions of flight software, as required throughout the mission.

6. Provide troubleshooting and maintenance of flight software. Also provide analysis and status of unusable (bad) memory address locations.

7. Maintain parameter and spacecraft state databases.

3.3 SCIENCE OPERATIONS TEAM

The Science Operations Team will ensure that the operations organization executes operations in accordance with the Investigation Description and Science Requirements Document (IDSRD).

Through this team, the investigative teams shall establish science objectives, plan science observations, be responsible for the overall operation of the instruments, perform science and instrument health analyses, provide results to other members of the Project, and archive data records as described in the Science Data Management Plan.

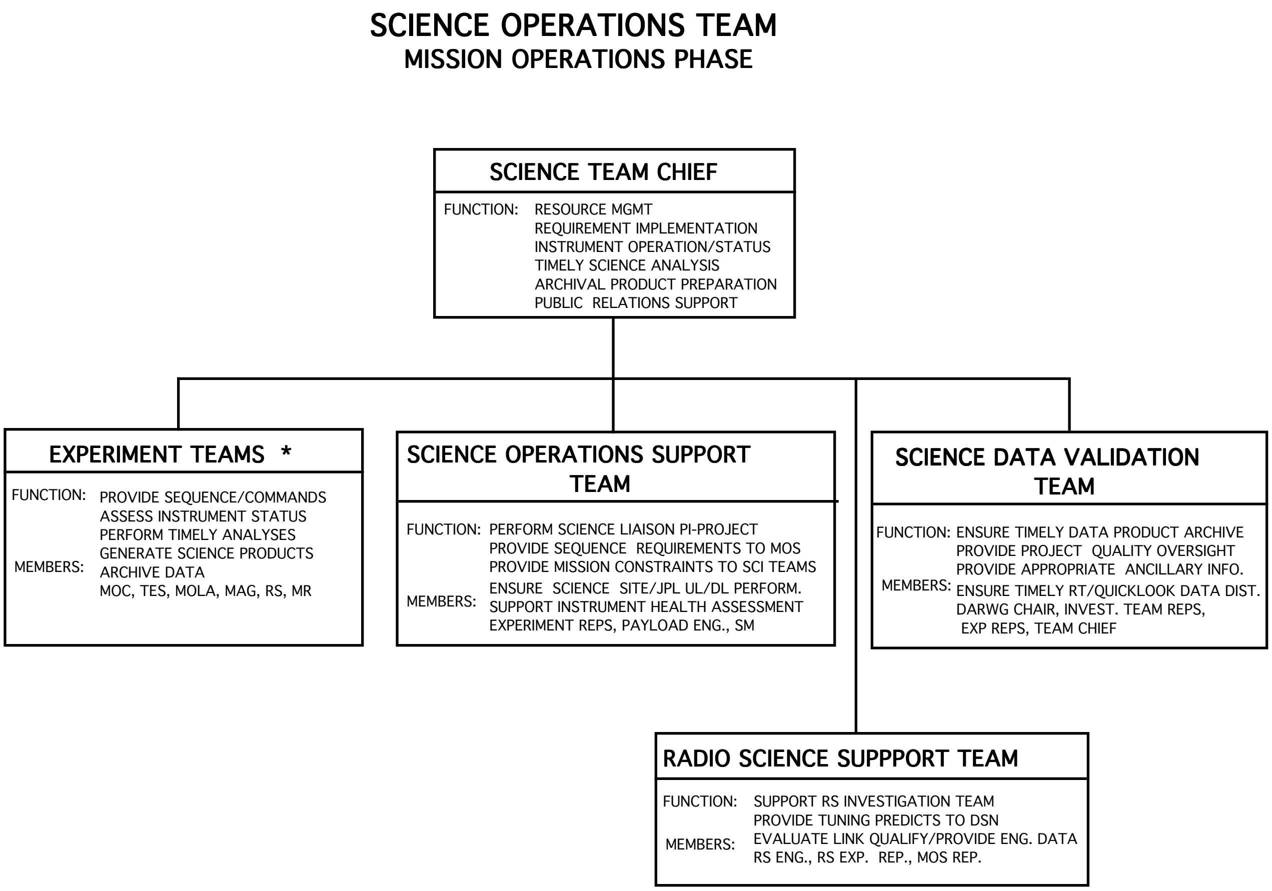
The Science Operations Team (see Figure 3-4) includes the Science Manager, the Science Operation Support Team, the Radio Science Support Team, the Science Data Validation Team, and the investigative teams.

The science teams are located remotely and consist of the following investigations:

- MGS Orbiter Camera (MOC), located at MSSS in La Jolla, California,
- Mars Relay (MR), located at CNES in Toulouse, France,
- MGS Orbiter Laser Altimeter (MOLA), located at GSFC in Greenbelt, Maryland,
- Thermal Emission Spectrometer (TES), located at ASU in Tempe, Arizona,

- Magnetometer/Electron Reflectometer (MAG/ER), located at GSFC in Greenbelt, Maryland,

- Radio Science (RS), located at Stanford University in Stanford, California.



*For purposes of this document: investigative teams includes only the Principal Investigators/Team Leader and his immediate operations staff (excluded are Co-Investigators, Inter-Disciplinary Scientists, Participating Scientists)

Figure 3-4

3.3.1 Instrument Performance Analysis

The Science Operations Team will provide instrument health evaluation reports, problem detection reports, and trend analyses as necessary to the Flight System Performance Analysis process to keep the project aware of instrument conditions.

It will provide inputs to the uplink process to operate the instruments. These inputs will include command requests, Spacecraft Activity Sequence Files, and stored sequence inputs. The SOT will receive inputs from the uplink process that will facilitate these tasks, including but not limited to, the stored sequences, DSN station allocation times, etc.

It will provide instrument alarm limits and updates to the Flight Systems Performance Analysis as they change.

The SOT requires inputs from different processes on the project to perform its functions. Instrument science and engineering data are required, including data that are incomplete or damaged. The SPICE information is also required.

3.3.2 Science Data Archive

It is the responsibility of the Investigative teams to deliver their data to the Planetary Data System for permanent archive. This will be done in a timely fashion per the Archive & Data Transfer Plan after receipt of data at their facilities.

3.3.3 Science Data System Maintenance

The remote investigation teams will be responsible for testing and maintaining the Science Data System at their sites. This includes their hardware and software but excludes SOPC hardware and software and connectivity to JPL. The downlink process will be responsible for the free flow of instrument data to the remote sites. The Project will assure maintenance of the MGSO supplied workstations. Each team will maintain their hardware and software as necessary to operate their instruments and evaluate their data. Configuration of both hardware and software facilities will be controlled within the Science Operations Team through site internal and Project Management using the Operations Facility Configuration Control Plan as baseline.

3.4 NAVIGATION TEAM

3.4.1 Navigation Team Organization

This section delineates the organization of the Navigation Team. It describes functional roles and responsibilities and the interfaces between the Navigation and other teams comprising the MOS.

The Navigation Team is responsible for spacecraft trajectory knowledge and control consistent with the mission and navigation plans and requirements. This broad navigational responsibility includes the following:

(1) trajectory and orbit determination and evaluation.

(2) propulsive maneuver analysis.

(3) trajectory and orbital analysis.

(4) navigational planning.

The team is led by the Navigation Chief, who is responsible to the Mission Manager. All team personnel are directly responsible to the Navigation Team Chief.

The functional organization of the Navigation Team is shown in Figure 3-5.

3.4.1.1 Team Chief

The Team Chief directs and coordinates the operations of the team to ensure that the functions are performed and products are generated consistent with Flight Team schedules. The Navigation Team Chief reports to the Mission Manager.

3.4.1.2 Trajectory and Orbit Determination and Evaluation Component

The trajectory and orbit determination component of the Navigation Team processes and analyzes radiometric data to determine the spacecraft's motion, its trajectory and orbit. In addition, all pertinent astrodynamical and physical constants and models are updated and refined. Trajectory errors are evaluated for reconstruction and, as necessary, are propagated to future times and events (e.g., Mars orbit insertion). The personnel responsible for this function shall accomplish the following:

(1) Determine the spacecraft's motion, trajectory, and orbit based primarily upon the analysis of two-way and three-way coherent Doppler, one-way non-coherent Doppler and range data.

(2) Determine radiometric data quality.

(3) Update and refine astrodynamical models and physical constants to ensure accurate reconstruction and prediction of the spacecraft's position and velocity.

(4) Support propulsive maneuver reconstruction.

(5) Participate in Test and Training and Readiness Testing activities conducted by the Project.

(6) Determine an accurate model of the gravity field of Mars as a result of data acquired during the Gravity Calibration period.

(7) Determine Mars' atmospheric density throughout aerobraking and whenever possible throughout the mapping phase of the mission.

Navigation Team Functional Organization

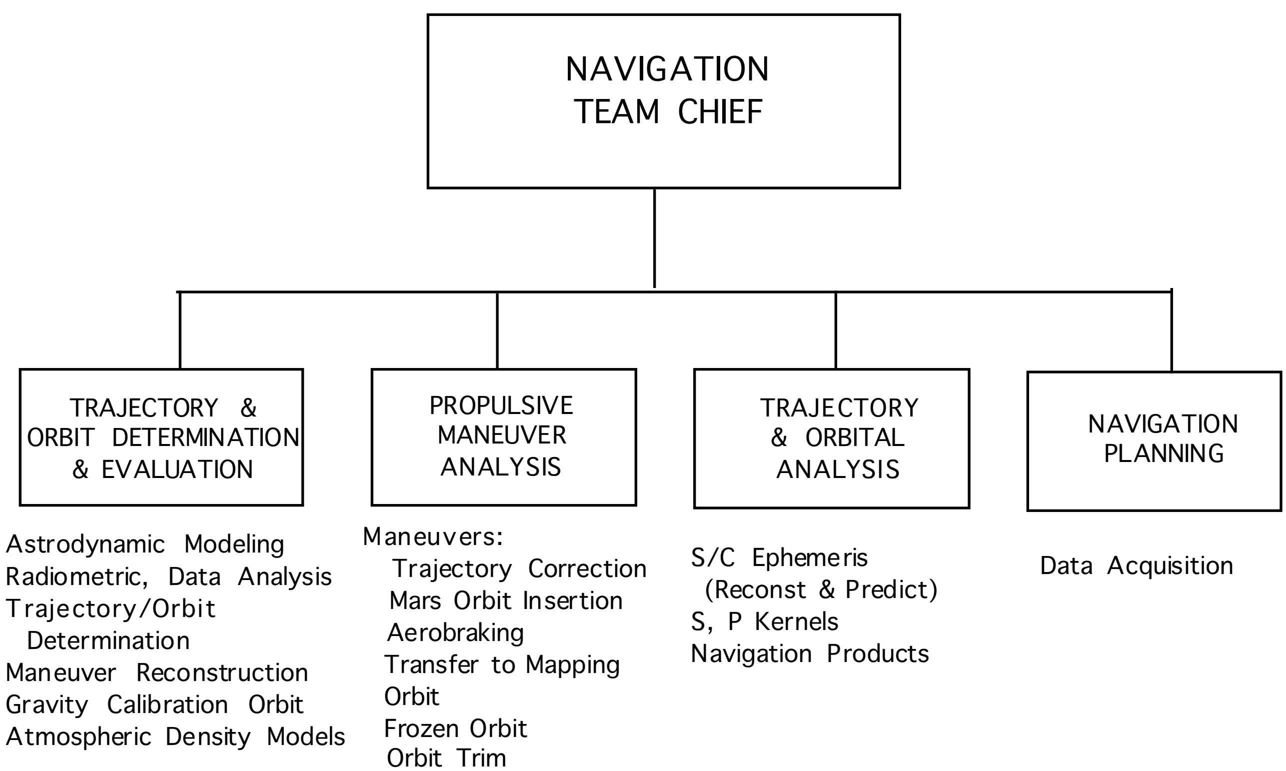


Figure 3-5

3.4.1.3 Propulsive Maneuver Analysis Component

The propulsive maneuver component of the Navigation Team specifies propulsive maneuvers and provides their initial design for implementation by the Spacecraft Team (SCT). This task requires close cooperation with the trajectory and orbit determination function, as well as the SCT. This activity will be conducted in accordance with the Mission Plan, the Mission Requirements Document, and the Navigation Plan. In addition, personnel responsible for Propulsive Maneuver Analysis shall participate in the reconstruction of propulsive maneuvers in order to support the SCT in performance analysis. The personnel of this component have the following responsibilities:

(1) Specify and design propulsive maneuvers associated with trajectory correction, Mars orbit insertion, aerobraking and the transfer to the mapping orbit, establishment of the frozen orbit and orbit trims for mapping orbit maintenance.

(2) Provide initial propulsive maneuver parameters to the SCT by the Maneuver Profile File. SCT response and implementation shall be provided through the Maneuver Implementation File.

(3) Support real-time maneuver execution evaluation, as required.

(4) Participate in propulsive maneuver reconstruction.

3.4.1.4 Trajectory and Orbital Analysis Component

The trajectory and orbital analysis component of the Navigation Team generates the trajectory and orbital motion of the spacecraft based upon the results of the trajectory/orbit determination component. This task includes generation and maintenance of trajectory/orbit reconstruction and prediction products. S and P kernels shall be generated on a Navigation Workstation with the software and tools provided by the Navigation Ancillary Information Facility (NAIF). The personnel assigned to this component have the following responsibilities:

(1) Based upon spacecraft and planetary ephemeris files, generate predict and actual S and P kernels using a Navigation Workstation and the NAIF software and tools.

(2) Generate light-times, eclipse and occultation times, as well as related trajectory/orbital products required as a result of team interface agreements.

(3) Deliver trajectory/orbital products to the Project Data Base (PDB) in SFDU (Standard Formatted Data Unit) format.

3.4.1.5 Navigation Planning Component

The navigation planning component of the Navigation Team determines navigation profile requirements and supports operations planning activities with the following responsibilities:

(1) Provide sequence plan inputs and assess impact of sequence plan conflicts and review sequence products.

(2) Provide planning information for data acquisition.

3.4.2 Navigation Operations Overview

For Navigation, mission operations are centered around a navigation computer upon which specially developed MGS navigational software will be repeatedly executed. In addition, the Navigation Workstations are an integral part of the analysis of radiometric data and the generation of navigation products, especially the S and P kernels. A generalized view of the flow of navigation-related, operational information is shown in Figure 3-6.

Overall Navigation Input/Output Functional Flow

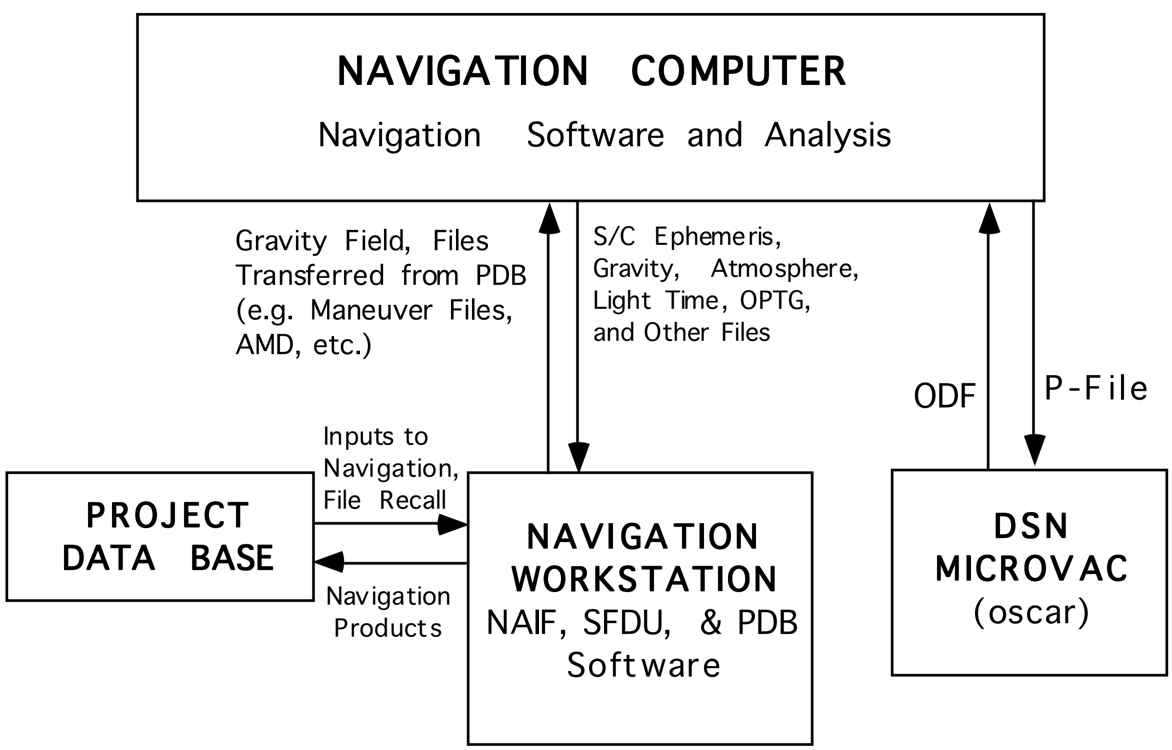


Figure 3-6

As with other teams, the Navigation Team's normal work-time encompasses an eight-hour, prime-time shift, five days per week (Monday through Friday). During critical activity periods (e.g., Launch, TCM's, Mars Orbit Insertion, etc.), the Navigation Team shall work as required in order to perform its functions.

The following sections describe navigation activities during mission operations.

3.4.2.1 Navigation Process Input

(1) Data products.

(2) Status reports.

(3) Operation profiles.

(4) Events profiles.

(5) Requirement reports.

(6) Schedules.

(7) Duty rosters.

All navigation inputs are accepted by the Navigation Team under the direction of the Navigation Team Chief.

3.4.2.2 Process

The Navigation Team Chief monitors team progress and provides direction, taking corrective action as necessary. The Team Chief schedules team activities and establishes priorities consistent with overall MOS requirements. The Team Chief provides the primary interface with the rest of the MOS, providing the team status, attending mission planning meetings, and approving all input and output products that interface with the Navigation Team.

3.4.2.3 Output

(1) Data products.

(2) Requirements.

(3) Profiles.

(4) Requests.

(5) Schedules.

(6) Reports.

(7) Staffing.

All Navigation Team products are delivered to the other members of the MOS under the direction and approval of the Team Chief.

3.4.3 Trajectory And Orbit Determination And Evaluation

3.4.3.1 Input

The input information and data to the trajectory and orbit determination and evaluation component of the Navigation Team consist of the following:

(1) Navigation constants and model inputs . These come primarily from the Planetary Constants and Models document and whatever current best estimates exist from publications and other documents.

(2) Planetary, natural satellite, and lunar ephemerides and related constants . Planetary and lunar ephemerides and partial derivative files are supplied to the Navigation Team through the MGSO. These files will be deposited on the NAV computer. Also contained therein are planetary constants such as planet masses, lunar mass, planetary radii, etc.. In addition to planetary position and velocity, their associated errors are also supplied. These files are required one year prior to launch (Nov. 1995). This requirement also applies to the Mars natural satellite ephemeris.

(3) Spacecraft physical quantities . The SCT shall provide the spacecraft's total mass, component dimensions, and quantities relating to the solar radiation pressure modeling. Information about spacecraft-self-induced accelerations as a result of angular momentum desaturation shall be supplied through angular momentum desaturation files. Quantities relating to the orientation of the spacecraft shall be supplied through the Navigation Engineering Information File (NEIF).

(4) Radiometric data, calibration and related information . Spacecraft tracking data measurements or observables are supplied through the following files: the ASCII Spacecraft Tracking Data file (ASTD), the orbit data file (ODF) and the archival tracking data file (ATDF). Data calibrations due to the troposphere, ionosphere, and, as appropriate, the interplanetary plasma are given on the MEDIA file. Troposphere calibrations shall be supplied before launch and may be updated monthly throughout Cruise. During the orbital phase, the troposphere file will be updated monthly. Ionosphere calibrations shall be supplied weekly via

electronic file transfers during Cruise. During the Orbital Phase, ionosphere calibrations shall be supplied daily.

Range calibrations due to the spacecraft time-delay, the ground time-delay and the Z-height station correction are also provided. Spacecraft time delay is measured before launch. Ground time delays are measured immediately preceding or following each tracking station pass. Z-height station corrections are measured infrequently.

Time and frequency offsets between hydrogen masers at each tracking station site shall be provided weekly during Cruise and daily during the Orbital Phase.

Related information consists of a time and polar motion file, tracking station coordinates and associated error. Time and polar motion files shall be supplied by the TSAC group weekly during Cruise. It will be supplied twice weekly during the Orbital Phase via electronic file transfers to and from the PDB.

(5) Injection state initial conditions. These are a set of initial conditions (effectively position and velocity of the spacecraft) resulting from the injection maneuver which places the spacecraft on its cruise trajectory to Mars. Navigation requires these in order to analyze the first set of DSN radiometric data which will be acquired immediately after injection. These initial conditions are generated from launch polynomials, which are required in two deliveries from McDonnell Douglas. The first delivery is one year prior to launch, with the second delivery six months prior to launch. In addition, three sets of initial conditions (called Inter Center Vectors) shall be provided for:

(a) Parking orbit,
(b) Post upper stage burn state prediction and
(c) Post upper stage state reconstruction.

3.4.3.2 Process

After all the above information has been assembled, this component will (a) analyze the radiometric data in order to determine the cruise trajectory to Mars and propagate errors to Mars encounter, and (b) during the orbital phase, complete a similar analysis and propagate the orbit for fourteen days. During cruise, the trajectory determination will be updated, on average, on a weekly basis. During the orbit insertion phase, orbit determinatin shall be daily except for the last third of aerobraking when it shall be accomplished three times per day. During the mapping orbit phase, orbit determination will occur on a daily basis in order to produce accurate orbit reconstruction information.

A complementary analysis shall yield predicted orbital information extending over a 14-day interval (starting at an initial epoch just prior to a tracking pass and extending fourteen days past the initial epoch).

This information shall be used to assess trajectory and orbital motion in order to achieve requirements levied on Navigation in the Mission Requirements and Science Requirements Documents. These results will also be used to initiate the planning and propulsive maneuver design processes.

Periods of intense activity for trajectory and orbit determination analysts have been identified at various intervals during the MGS mission. The most intense period will be during aerobraking and gravity calibration (GC). During GC, tracking data will be acquired continuously for seven consecutive days. The OD analysts are then allocated approximately two weeks to analyze this data and develop a Mars gravity field model (a 30x30 model). Other periods of high activity include the three weeks preceeding TCMs and orbit insertion maneuvers. The latest tracking data files will be used in support of these maneuvers so that the propagation of errors between orbit update and maneuver execution is kept small. Four TCMs are planned to maintain the spacecraft on the proper trajectory towards Mars. During orbit insertion, propulsive maneuvers and implementation of the aerobraking strategy are required to place the spacecraft into the mapping orbit around Mars.

Orbit determination analysts shall routinely refine dynamic spacecraft models as necessary. The effects of solar radiation pressure, angular momentum desaturations, and Mars' atmospheric density on the spacecraft's motion will be observable in the radiometric tracking data.

3.4.3.3 Output

The results of this process include:

(1) Updated and predicted estimates of the spacecraft's state along with error estimates which are used to initiate the planning and initial maneuver design processes.

(2) Refined astrodynamical models and physical constants which together with the General Input (GIN) file and planetary ephemerides provide inputs to the trajectory and orbit analysis function.

(3) An independent assessment of the execution of a propulsive maneuver. Quantities such as the change in velocity (i.e., delta-V) and error estimate and the resultant targeted aim-point will provide input to the planning and maneuver process and to the SCT.

(4) Radiometric data quality and quantity assessment for use in planning future data acquisition.

(5) P-file for use by the DSN. This is not a SPICE kernel product.

3.4.4 Propulsive Maneuver Analysis

3.4.4.1 Input

The input information and data to the propulsive maneuver analysis component consists of the following:

(1) Planning guidelines, strategy development and mission requirements _. These are provided by extensive pre-operations analysis documented in the (a) Mission Plan, (b) Navigation Plan, (c) Mission Requirements Document, and (d) Mission Sequence Plan.

(2) Spacecraft and planetary ephemerides . Spacecraft state vectors as well as an estimate of error and planetary ephemerides are provided by the trajectory and orbit determination analysis component.

(3) Propulsive maneuver execution error model _. Initially this model is provided by the spacecraft contractor and the SCT. Navigation analysis of radiometric data shall provide an independent assessment of the propulsive maneuver error model.

(4) Injection state and error. Initially, the injection maneuver error model and updates are provided by the upper stage contractor. Immediately after the acquisition and analysis of radiometric data, Navigation shall assess the results of the injection and provide targeting estimates.

(5) Maneuver reconstruction using spacecraft telemetry data . An independent assessment of propulsive maneuver execution and error shall be made by the SCT through analysis of telemetry data.

3.4.4.2 Process

The propulsive maneuver analysis component participates in the planning, design, implementation, and reconstruction of propulsive maneuvers. A schedule of propulsive maneuvers is specified in the Mission Plan. The maneuver design and implementation process begins with an initial computation of the delta-V required to obtain the desired targeting conditions. This delta-V estimate is then transferred to the SCT where it is used to develop a thrust profile. The SCT determines an effective thrust magnitude from the thrust profile and reports it on the maneuver performance data file (MPDF). Using the MPDF, the maneuver analyst designs an idealized propulsive maneuver and transfers this design to the SCT by way of the maneuver profile file (MPF). The SCT converts this idealized design into a realistic implementation (the maneuver implementation file, MIF) and iterates with the Navigation Team until a joint acceptance of the maneuver implementation results.

The maneuver reconstruction process begins immediately after maneuver execution. If real-time radio tracking data is available through the maneuver, the propulsive maneuver analysis component shall monitor the data in order to provide a preliminary assessment of the maneuver. A more detailed and accurate reconstruction of the maneuver shall be provided jointly by the propulsive maneuver analysis component and trajectory and orbit determination and evaluation component by processing radiometric data through the Orbit Determination Program (ODP). At the same time, the SCT will reconstruct the performance of the maneuver by way of the spacecraft's telemetry data.

In general, this operating plan will be repeated for all propulsive maneuvers. If, during the orbital phase, propulsive maneuvers become too frequent to make this plan practical then only a subset of these maneuvers shall be analyzed in this detail. Maneuver profile files shall be prepared in accordance with the timelines developed by the project.

Periods of intense activity for maneuver analysts have been identified at various intervals during the MGS mission. These periods include the two weeks before TCMs and the orbit insertion maneuver, when design and verification of maneuver models will occur. The entire aerobraking phase shall be an intense activity period for the Navigation Team.

Maneuver analysts shall routinely design orbit trim maneuvers (OTMs). These maneuvers will occur approximately every six weeks during the mapping phase to maintain the mapping orbit.

3.4.4.3 Output

The results of this process include:

(1) Initial design of the propulsive maneuver including strategy, profile, timeline and predicted target delivery accuracy. The maneuver profile file provides input to the SCT for implementation of the maneuver.

(2) Real-time monitor information (whenever tracking data is available) providing a preliminary assessment of the execution of a propulsive maneuver.

(3) Jointly with the trajectory and orbit determination group, provide a post-maneuver reconstruction from which the performance of the maneuver shall be assessed.

3.4.5 Trajectory And Orbit Analysis

3.4..5.1 Input

The input information and data to the trajectory and orbital analysis component of the Navigation Team consists of the following:

(1) Navigation constants and models file (GIN). This file contains all the acceleration models, as well as numerical integration error control necessary to integrate the spacecraft's equations of motion. The GIN file is a composite of dynamic and non-dynamic models and parameters of which the following are subsets or components: spacecraft initial conditions at injection or other epochs, the spacecraft's mass, configuration and dimensions for solar radiation pressure, spacecraft self-induced accelerations due to angular momentum desaturation as well as other non-gravitational forces, propulsive maneuver instantaneous and finite-burn models and so on.

(2) Planetary and lunar ephemerides.

(3) Astrodynamical and physical constants file. This file shall contain updates and refinements to the above models and parameters which are deduced primarily from the analysis of MGS radiometric data. This includes, for example, Mars' gravitational field model deduced from the analysis of the GC data, atmospheric density profiles, the effective velocity-change due to a propulsive maneuver, and refinements of parameters used to define the solar radiation pressure model.

3.4.5.2 Process

The operational responsibilities of this component are:

(1) Specification of trajectories and orbits which satisfy mission requirements.

(2) Computation of spacecraft ephemerides and related products (e.g., light-time, eclipse times, ...) which are required as a result of team interface agreements.

(3) Maintenance of a trajectory product and model database.

(4) Participation in the validation of propulsive maneuvers design and implementation models.

The generation of spacecraft ephemerides is coupled to the trajectory/orbit determination task. Spacecraft ephemerides shall be generated daily (excepting weekends and holidays) for reconstruction and weekly to satisfy the 14-day prediction requirement throughout the mapping phase. At times, the spacecraft ephemeris may be generated more frequently in order to satisfy prediction requirements. Trajectory/orbit-related products required from Navigation are specified by interface agreements. Spacecraft and planetary ephemerides will be electronically transferred from the navigation computer to a Navigation workstation where they will be converted to a single unified file, called the Spacecraft Planetary Ephemeris Kernel (SPK) file. NAIF software will be used in the process of generating the SPK file and transferring it to the PDB. With the exception of P-files, all Navigation products will be transferred via a workstation from the navigation computer to the PDB. P-files shall be transferred to the DSN Microvax computer "Oscar," where they shall be retrieved by the Multimission NAV Team. The MMNAV Team will then transfer them to the DSN Microvax computer "Froggy," where they shall be retrieved by the DSNOT.

Periods of intense activity for the trajectory analyst are the same as those periods for maneuver analysts, because the trajectory analyst participates in the verification of maneuver models.

3.4.5.3 Output

The results of the trajectory and orbital analysis component are:

(1) Reconstructed and predicted spacecraft ephemerides. These will be transferred to the Navigation workstation (along with the planetary ephemeris) to produce S and P kernels which will appear on the PDB as the spacecraft-planetary ephemeris (SPK) file.

(2) Other Navigation products resulting from team interface agreements. These products include the following: one-way light time file, station polynomial file, planetary constants kernel (PCK) file, astrodynamical and physical constants.

(3) Navigation-internal information and data. This data primarily includes trajectory/orbital geometric data used by various members of the Navigation Team.

3.4.6 Navigation Planning

3.4.6.1 Input

The input information to the navigation planning component consists of the following:

(1) Project planning and guidelines documentation and reports. These consist of, for example, the Mission Plan, Mission Requirements Document, Science Requirements Document, Navigation Plan, Mission Sequence Plan, DSN tracking schedules, spacecraft activity sequence files, enhanced predicted events files, and propellant utilization and status from the SCT.

(2) Integrated inputs from Navigation Team components . These include current trajectory and orbit determination knowledge as well as propagated errors to various times or events (e.g., Mars orbit insertion), current orbit parameters and predicted orbital evolution especially due to drag and Mars' gravitational field and nominal propulsive maneuvers plans and timelines.

3.4.6.2 Process

The planning function shall support the control component in monitoring overall team progress in maintaining navigation-mission objectives and achieving navigation requirements. More important, this component shall plan activities to assure that these objectives are accomplished.

These activities include (a) participating in data acquisition planning, (b) providing supporting analysis to modifications in the nominal mission plan and operations, and (c) providing integrated navigation inputs to the planning and sequencing process.

3.4.6.3 Output

The navigation planning component shall produce:

(1) Plans for and inputs to radiometric data acquisition.

(2) Integrated navigation inputs to the planning and sequencing process.

(3) Plans for propulsive maneuver strategies which satisfy mission requirements and science objectives.

(4) Evaluation of modifications or options to the baseline mission and navigation plans.

3.4.7 The Navigation Subsystems: Integrated Flow Of Information

All the information, data and products mentioned in the preceding six subsections and their flow into, around, and out of the Navigation Subsystem are shown in Figure 3-7. This figure stresses basic information flow; internally generated information used by various navigation components is only partially shown.

Mars Global Surveyor Navigation: Data Flow Functional Description

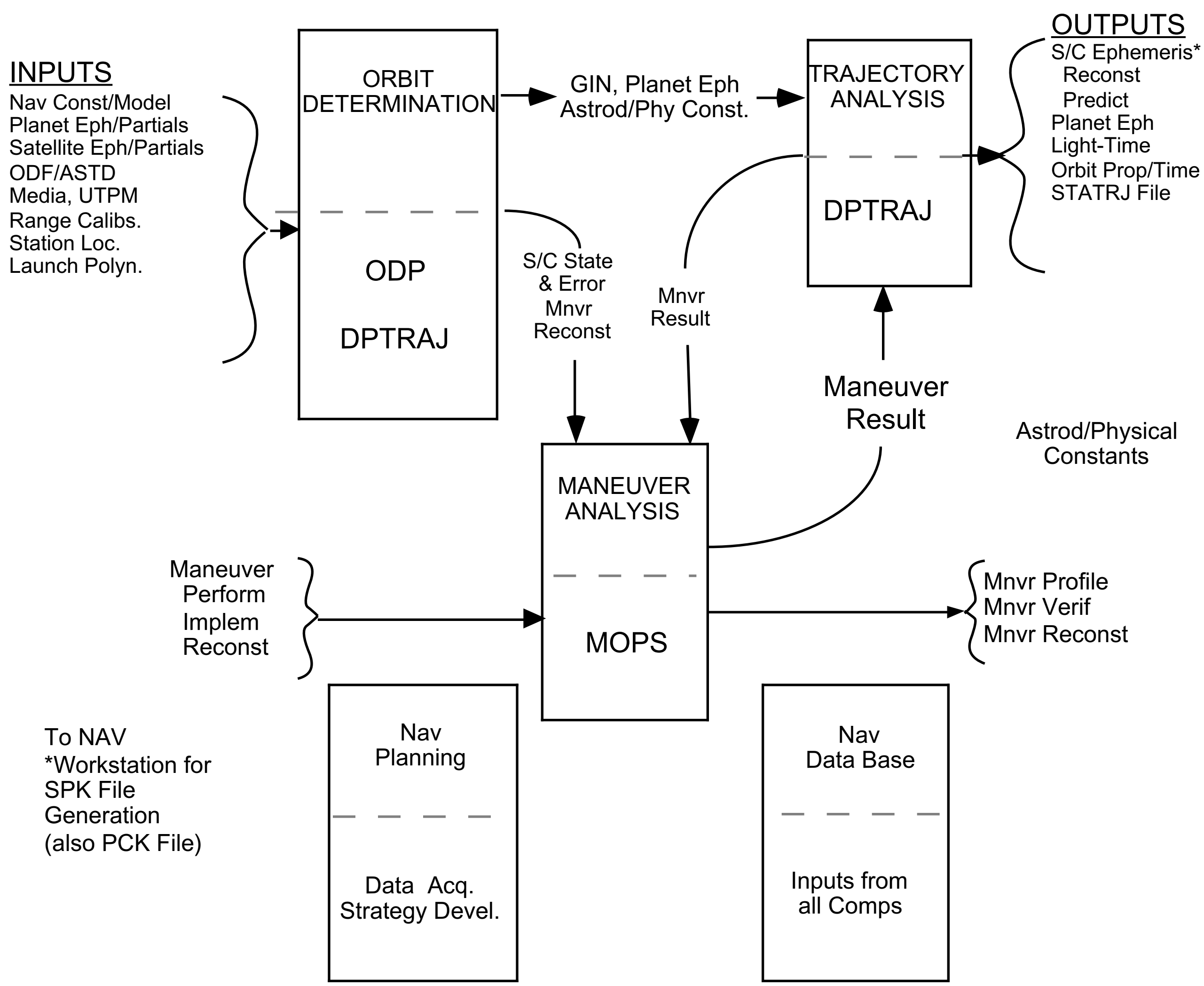


Figure 3-7

3.5 SEQUENCE TEAM

The Mars Global Surveyor Sequence Team (SEQ) will support the planning and implementation of Mars Global Surveyor science observations and engineering activities and their integration into complete spacecraft sequences of activities. This task will include sequence expansion and constraint checking for Flight Team review, as well as generation of the Ground Command File (GCMD) to be sent to the spacecraft, loaded into memory, and executed onboard.

The organization of the SEQ is described in terms of the team positions and their responsibilities.

Throughout this section the term "Requestor" refers to, at least, principal investigators, the Spacecraft Team, and the Navigation Team.

The Mars Global Surveyor Sequence Team (SEQ) shall be organized in the following manner (see Figure3-8):

(1)	Team Chief	one person
(2)	Sequence Integration Engineer (SIE)	
	(a) Stored Sequence SIE	two people
	(b) Non-stored Commanding SIE	two people
(3)	Uplink Operations Engineer (UOE)	one person

The following functions shall be performed by the Mars Global Surveyor SEQ:

(1) Develop and integrate the pre-launch generated sequences.

(2) Create sequence data products for review and approval.

(3) Receive and process sequence activity requests.

(4) Integrate skeleton sequences of activities.

(5) Operate the sequencing software during the sequence integration process.

(6) Process non-interactive payload command (NIPC) requests.

(7) Generate Ground Command Files (GCMD) for transmission to the spacecraft for execution onboard.

(8) Process spacecraft coordinated (non-stored) command (CC) requests.

(9) Process spacecraft Express (non-stored) command (EC) requests.

The following subsections describe the functions of the SEQ members.

3.5.1 Team Chief

(1) Produce SEQ schedules for the generation of spacecraft sequences and products.

(2) Define, negotiate and approve all inter-team interfaces necessary for the SEQ.

(3) Manage the SEQ. Assure that all sequencing procedures are followed and that all scheduled milestones are met. Maintain smooth operation of the Team during the processing of spacecraft sequences.

(4) Approve the sequence. Sequence products, including the GCMD, shall be among those requiring Team Chief signature.

(5) Be the focal point for all inter-team policy-related negotiations, interfaces, and/or problems.

3.5.2 Sequence Integration Engineer (SIE)

(1) Keep the Team Chief informed of the status of all sequencing related activities on a regular basis. Also keep the Team Chief informed of any problems that arise during the sequencing process.

(2) Lead the Flight Team in building and integrating pre-launch developed MOS Compatibility (MOSC) sequences. This leadership role shall require that the SIE be the cognizant person for all pre-launch developed (MOSC) sequences during the development period and play an active role in constructing the sequences.

(3) Integrate the pre-launch developed sequences, using various components of the Planning and Sequencing Element, into functional sequences. These sequences will then be saved by the SIE as data products on the PDB to be accessed by the requesters during the sequence development process.

(4) Lead the Sequence Team through the Sequence Development Process.

(5) Be the focal point for all inter-team sequence-related negotiations, interfaces, and/or problems.

(6) Have the authority to make decisions relating to a developing sequence. These decisions shall be based on team and project guidelines and policies.

(7) Act as the coordinator for processing of all non-stored commanding.

(8) Verify that all required solid state recorder (SSR) events occur at the time required and that the correct SSR command occurs for each sequence during its development process.

(9) Perform any necessary SSR managment to maintain SSR health.

(10) Validate that all system-related commands are properly implemented for each sequence. These will include spacecraft commands as well as any identified instrument commands.

(11) Verify that spacecraft telecom data link is in accordance with the Mission Specifications for the period in question and in accordance with that supportable by the DSN. Verification will be by review of various products from the sequence development process.

(12) Verify that all necessary managment of the Payload Data Subsystem (PDS) is performed as required.

(13) Verify that the proper spacecraft subsystem is given the real-time data link by verifying that the proper data mode is used.

(14) Verify that all non-stored commands requested are allowable, per Mission Guidelines.

(15) Operate all SEQ software during the sequence integration and implementation process. Also operate the SEQ software during processing of non-stored command (NIPC,EC and CC) requests.

(16) Maintain records of all Sequence Team data entities. These shall include sequence data products and software support files.

3.5.3 Uplink Operations Engineer (UOE)

(1) Coordinate day-to-day SEQ team operations.

(2) Maintain and monitor the NIPC Process. This subprocess shall reside on the team chief's workstation. The UOE shall assure that the process is operational during standard work hours. The UOE shall also be required to monitor the process regularly for correct operation.

(3) Maintain and monitor the Automated Command Toolkit (ACT) system. The UOE shall assure that the process is operational 24 hours a day, 7 days a week. The UOE shall also be required to monitor the process regularly for correct operation.

Sequence Team Organization

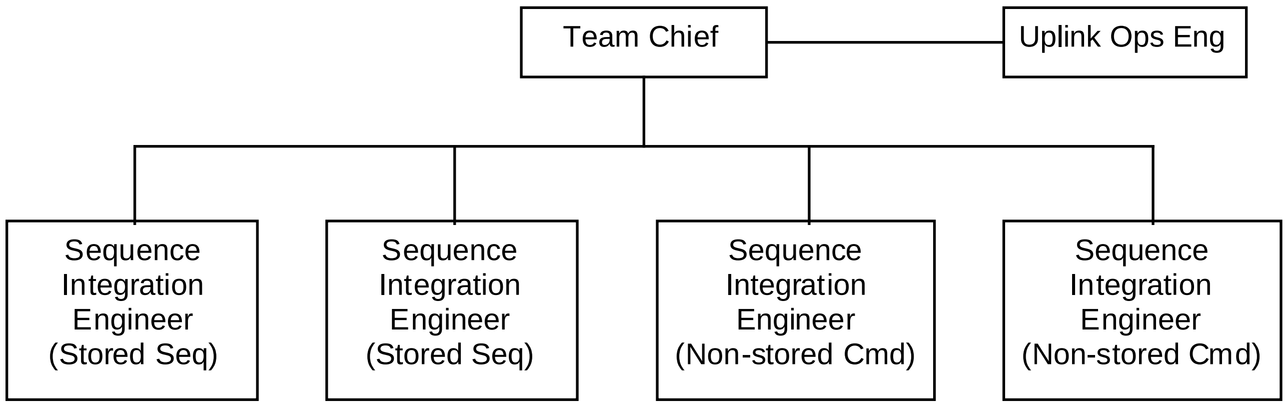


Figure 3-8

3.6 MISSION OPERATIONS ASSURANCE TEAM (MOA)

The MOA is the project team that shall be responsible for the following tasks:

1) MOA Team Lead
2) Anomaly Management
3) Configuration Management
4) System Administration
5) Project Database (PDB) Administration
6) Data Archival
7) E-KERNEL Generation
8) Training
9) MOS Documentation/Library

The structure of the MOA Team is shown below. The Team Chief is a working member of the Team.

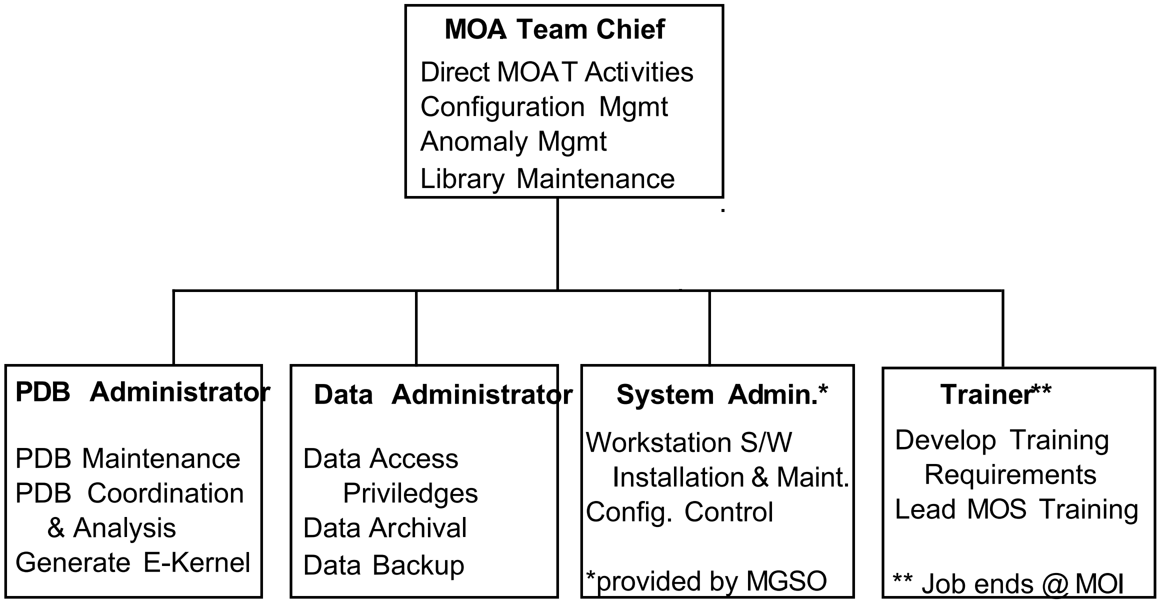


Figure 3-9
MOA Team Organization

3.6.1 BACKGROUND

Significant reductions (from Mars Observer levels) in MGS mission operations staffing are planned. Functions that are allocated to the MOA are dissimilar and cross team boundaries in the MGS MOS. These functions have been inherited from numerous JPL flight projects and most recently the Mars Observer Project. At first glance it would seem that MOA is the catch all for the odds and ends of things necessary to project management and other MGS teams for day to day operations of the MGS MOS. These functions can only be accomplished within allocated resources, with a reduction in scope (for some), enabling technologies from MGS re-engineering and further reduction of project requirements for
quality, quantity and continuity of project data.

3.6.2 TEAM RESPONSIBILITIES

The responsibilities for each of the functions within the team are as follows:

1) Team Lead, Anomaly/Configuration Management Engineer, Library Archive

(a) Perform team operations planning and directs activities of the MOA team.

(b) Provide interface to Project Staff and assume MOA staff responsibilities.

(c) Oversee Anomaly Reporting and CM process.

(d) Assign and Categorize Anomaly Reports and Change Requests.

(e) Provide configuration control for all items in the MGS configuration control inventory.

(f) Maintain MOS library of electronic documentation.

(g) Perform trend analysis and/or status reports on anomaly and CM data.

(h) Ensure adequate anomaly report closure.

2) PDB Administration and E-KERNEL Generation

(a) Provide off-line coordination and analysis of Project Data Base (PDB) operations, including data storage, retrieval, and maintenance.

(b) When necessary, converts data from one storage medium to another to satisfy storage and transfer requirements.

(c) Implement procedures for allocation of database access privileges and monitors MGS data security policies.

(d) On a three to six month interval (six months for cruise phase and three months for mapping operations) this file is extracted and wrapped with necessary PDS header information and declared the E-KERNEL.

(e) Accumulate data necessary for MGS level-0 archive volumes.

(f) Organize and create MGS Level-0 archive volumes on CD-ROM.

(g) Deliver Level-0 archive volumes to the PDS.

3) Data Administration

(a) Ensure that project data are maintained in the PDB and that all new data in the project database is backed up daily.

(b) Archive all raw science and engineering data and ensure transfer to the PDS.

(c) Archive all text files from electronic mail.

(d) Maintain a common log on the MGS Server (includes experimenter notebook comments).

4) MGSO System Administration Responsibilities

(a) Provide the high-level security interfaces between the Project and MGSO in accordance with the TMOD IOM (RP-May 1995-Rev.A) and the Project Security Requirements document (542-111).

(b) Provide configuration control of all MGSO/AMMOS ground data system elements required to support the Mars Global Surveyor Project.

(c) Install new MGSO deliveries on all required workstations.

(d) Solve connectivity/access problems on workstations.

5) Training Engineer

The training Engineer is responsible to the Mission Manager for the training of Mars Global Surveyor personnel. Specifically, the Training Engineer shall:

(a) Develop MOS Flight Team training requirements.

(b) Monitor and report on inter-team training activities and status.

(c) Conduct scenario training, walkthroughs, rehearsals, and operational readiness tests, which address those position tasks requiring team interaction under operational conditions.

(d) Prepare presentations for educational and training purposes.

3.7 MISSION MANAGEMENT

3.7.1 Mission Manager

The Mission Manager directs overall operations of the Mars Global Surveyor Flight Team, provides recommendations to the Project Manager for non-nominal and contingency operations, and directs the implementation of contingency plans, when required. The Mission Manager is supported in all respects by a Deputy Mission Manager who is authorized to act in behalf of the Mission Manager in the event of his absense.

Specifically, the Mission Manager shall:

(1) Approve maneuver design.

(2) Chair the Maneuver Review and approve commandable maneuver parameters.

(3) Chair the Project command conferences and approve all commands and sequence loads before each transmission.

(4) Approve all pre-launch developed MOS test sequences.

(5) Chair final sequence product reviews and approve final sequence products.

(6) Chair the Mission Operations Change Board and approve all Mission Operations changes.

3.7.2 Telecommunications and Mission Services (TMS) Manager

The TMS Manager for Mars Global Surveyor is appointed by the Manager, Telecommunications and Mission Operations Directorate (TMOD), with the concurrence of the Mars Global Surveyor Project Manager. The TMS Manager is the formal point of contact between the Telecommunications and Mission Operations Directorate and Mars Global Surveyor Project and is responsible for the overall planning and coordination of MGS configuration specifications, implementation, and operation of the facilities and data systems that are provided by the Telecommunications and Mission Operations Directorate in support of Mars Global Surveyor. The TMS Manager will provide functions including the following:

(1) Commit Telecommunications and Mission Operations Directorate support to Mars Global Surveyor as the agent of theTMOD.

(2) Focus all interactions between TMOD and Mars Global Surveyor, including the establishment and documentation of commitments on behalf of TMOD for all support provided.

(3) Maintain an understanding of the requirements, plans and mission operational needs of Mars Global Surveyor and represent them within the TMOD.

(4) Coordinate the preparation of the Telecommunications and Mission Operations Directorate commitment documents in accordance with the TMOD Commitment Process Plan.

(5) Prepare and maintain Level-3 schedules for TMOD and Mars Global Surveyor and such subordinate schedules as may be required to track progress and status.

(6) Ensure that the data interfaces between Mars Global Surveyor and the TMOD-provided GDS elements are understood, that the interfaces are properly documented, and that TMOD-provided capabilities meet those interfaces.

(7) Ensure that operations requirements are understood and properly documented, and that committed support is available, as negotiated through close liaison with the SFOF Manager and theProgram Element Manager.

(8) Assure adequate TMOD review of the designs of TMOD-provided system elements to ensure that they meet commitments to Mars Global Surveyor.

(9) Support the Project in acquiring the TMOD resources necessary to meet Project requirements.

(10) Participate in the design phase of the approved Project to promote use of multimission Deep Space Network (DSN) capabilities as design parameters.

(11) Match the network tracking and data acquisition requirements of the flight project with the capabilities of the network support facilities, and ensure their documentation in the Mission Requirements Request (MRR) and the Detail Requirements Request (DRR).

(12) Ensure that the Project commitments are properly conveyed to the Network Operations and Implementing organizations and monitor progress in meeting performance and schedules.

(13) Ensure that the necessary Project required NASCOM interfaces are established and verified between elements of the Project and external agencies.

(14) Recommend changes to requirements and/or resources in order to meet overall objectives and approve detailed changes within original or amended overall TMOD commitment.

(15) Ensure that TMOD performance commitments stated in the DMR are met.

(16) Support the Project in the resolution of problems arising out of non-standard situations encountered during a mission.

(17) Ensure satisfactory spacecraft-DSN compatibility testing is performed and documented.

3.7.3 Ground Data System Engineering

The Ground Data System Engineer is responsible to the Mission Manager on all ground data system engineering activities. The Data System Engineer provides the following specific functions:

(1) Provide the integration and direction to the GDS maintenance activity.

(2) Review and approve all data system deliveries to MGS.

(3) Provide analysis of all data system anomalies, including spacecraft and GDS anomalies relating to data formats and data flow.

(4) Represent the Project on all ground data system interfaces between the Project and theTMOD.

3.7.4 Mission Planning

The Mission Planning function consists of the Mission Planning Engineer and the Resource Scheduler.

3.7.4.1 Mission Planning Engineer

In general, the mission planning engineer is responsible for ensuring the mission objectives are met through the implementation of the on-board flight sequences and is responsible to the Mission Manager for all mission planning engineering activities.

The Mission Planning Engineer provides the following specific functions:

(1) Maintains the Mission Plan (MP) and the Mission Sequence Plan (MSP).

(2) Reviews and impacts all sequence change requests.

(3) Reviews and impacts all Incident, Surprise, or Anomaly Reports (ISAs), DSN Discrepancy Reports (DRs) and Failure Reports (FRs) for sequence impacts.

(4) Generates the Spacecraft Activity Sequence File (SASF) from the skeleton sequence timelines in the MSP, as input to the sequence development process.

(5) Reviews sequence products and supports Mission Manager's Sequence Approval Meetings

3.7.4.2 Resource Scheduler

In general, the Resource Scheduler defines, documents and coordinates the Project's DSN tracking requirements for long range planning and sequence generation use.

The Resource Scheduler provides the following specific functions:

(1) Generates the Long Range Deep Space Network utilization forecast for the life of the Project.

(2) Negotiates mid-range (60 days- 6 months) tracking requirements and obtain committed tracks.

(3) Generates the Resource Allocation File and provides it to the Uplink process for sequence generation.

(4) Coordinates changes to the committed DSN tracks with all elements of the Flight Team.

APPENDIX A

TABLE OF CONTENTS

MGS Aerobraking Operations Strategy and Overview

1.0 OVERVIEW

The flight team responsibilities during aerobraking include spacecraft commanding (through use of stored commands and real-time commands) to perform the required orbit events. In adition, the flight team will perform navigation orbit determination, atmospheric modeling, and routine spacecraft health monitoring.

There are two critical spacecraft orbital events which must be commanded by the ground in order to execute aerobraking successfully. The first spacecraft event is performed every orbit around periapsis to configure and orient the spacecraft for entry into the atmosphere. This event is executed via initiation of a reusable command script which is resident on-board and stored in the mission phase script area of onboard memory. This drag pass command script is generated/updated by a ground resident command block called AEROBRAKE, which resides in the sequencing software. The on-board drag pass sequence is initiated via “start script” or trigger commands which are loaded as stored sequence command files as frequently as needed to meet navigation periapsis timing error prediction requirements. In addition to the sequence of trigger commands, the spacecraft attitude control software requires a Mars ephemeris in order to maintain the proper nadir attitude throughout the drag pass. The NAV Update Process is the process used for executing the drag pass event each orbit.

Associated with the AEROBRAKE block are specific parameters which allow the relative timing between the events to be adjusted as the orbit period decreases. Periodically, the block will be rerun on the ground to adjust the block timing and the resulting sequence reloaded on the spacecraft into the appropriate reusable script area. The Underlying Sequence Update Process is the process used to accomplish this.

The second critical spacecraft orbital event is the propulsive maneuver at apoapsis (aka ABM) which is executed as needed to maintain the required periapsis altitude. The ABM command script is generated by a ground resident command block called “ABM” and stored on-board the spacecraft similar to the drag pass script and is initiated via a real-time “start script” or trigger command. The ABM Decision and Implementation Process, described below, is the process for executing an ABM.

Operations during the aerobraking mission phase will be as routine and repetitive as appropriate for safe and proper operation of the spacecraft. Six basic processes have been defined which will satisfy all commanding requirements. What follows is a brief description of each of these processes, including the frequency of their use and any teams involved. After the description of each of these processes a discussion of the manner in which these processes integrate together during aerobraking operations will be given.

1.1 NAV Update Process

This process is invoked regularly by the flight team to generate the commands required to trigger the onboard aerobraking drag pass script and to update the onboard ephemeris, which is required to maintain proper spacecraft drag attitude through the drag passes. One process cycle will be triggered by each periapsis until the orbit period is less than seven hours. After this time the one process cycle will predict more than one orbit ahead, which will avoid requiring more than one cycle running simultaneously. The teams involved in this process are SCT, NAV, SEQ and RTOT. The process also includes a review of the data to be uplinked and Mission Manager approval before the commands are radiated.

1.2 ABM Decision and Implementation Process

This process will be applicable to the small walkin maneuvers (AB2, AB3, AB4) and all corridor control maneuvers (ABMs). A single generic script which can perform these maneuvers will be stored in the mission script area of onboard memory. Parameters for this script will be determined and generated by using this process. The process begins with an independent assessment of current aerobraking operation by an Aerobraking Planning Group composed of the mission planning engineer and representatives from NAV and SCT. Within the bounds of operating guidelines defined by the project, this group collectively decides upon the timing and delta-V magnitude of the next ABM maneuver. If this group decides that an ABM maneuver is necessary, then the SCT will create a Spacecraft Activity Sequence File (SASF) containing the request/script trigger command. This group will also immediately forward its recommendation to the Mission Manager for final approval. If the Mission Manager concurs, then the SASF will be submitted by the SCT to the SEQ’s Express Command (EC) process.

To expedite this process while reducing risk of miscommanding, a strategy has been implemented which uses a look-up-table of the orbit argument of periapsis versus quaternion. The data contained in the table are derived from the aerobraking reference trajectory. From this trajectory it can be determined how the argument of periapsis changes over the time covered by the AB profile. From these data can be derived thrust vector information from which UP and DOWN quaternions can be generated. The current trajectory profile indicates that argument of periapsis ranges in value from $+160^{o}$ to -60^{o}. Two separate tables will be generated. One will be for UP maneuvers and the other will be for DOWN maneuvers. This helps reduce the risk of choosing the wrong direction quaternion set from a file containing both sets. An initial table will be generated pre-MOI (MOI-90[d]), however, it may require updating after MOI if the MOI maneuver is significantly different from the planned MOI.

Finally, the magnitudes of the AB2-AB4 and ABM maneuvers will be quantized. This quantization will be for a “full” size maneuver, a “half” size maneuver and a “double” size maneuver. The actual numeric value of “full” may need to be updated occasionally to account for changes in walkin conditions or unexpected atmospheric conditions.

1.3 AB1 and TMO Maneuver Design Process

This process is used to design the AB1 and TMO maneuvers. The process begins with two full days of tracking data acquisition. This is followed by a period of orbit determination. The maneuver is then designed and expressed as a sequence input file (SASF). This file is processed through the sequencing system and data products are provided for flight team review and testing on the STL. Once the maneuver is verified through the sequencing system and the STL the file will be submitted for Mission Manager approval. If approval is granted, then the maneuver will be sent to the spacecraft for storage onboard and eventual execution. The total duration of this process is 57 workhours (~7 workdays). It is performed during standard work shifts and only as needed to generate one of the above mentioned maneuvers. The participating teams are SCT, NAV, SEQ and RTOT.

1.4 Underlying Sequence Update Process

This process is invoked to update the Aerobraking script or the ABM Master script. It is also used to issue any special commands which may be necessary for operation of the spacecraft and for any commanding necessary to support science data collection. It is an off-line process. This means that it can be performed during a standard workday. It is expected to occur no more than once per week. The total duration of the process is 13 workhours. However, this is divided into two periods. The first is eight hours in length and is comprised of building the necessary sequence input files (SASF), completing their processing through the sequencing system, reviewing the resulting command files and initiating and executing a run of the Spacecraft Test Laboratory (STL). The final five hours, which occur on the following workday, are devoted to reviewing the STL run and obtaining final Mission Manager approval for radiation. The teams participating in this process are SCT, SEQ and RTOT.

1.5 Spacecraft Health Monitor Process

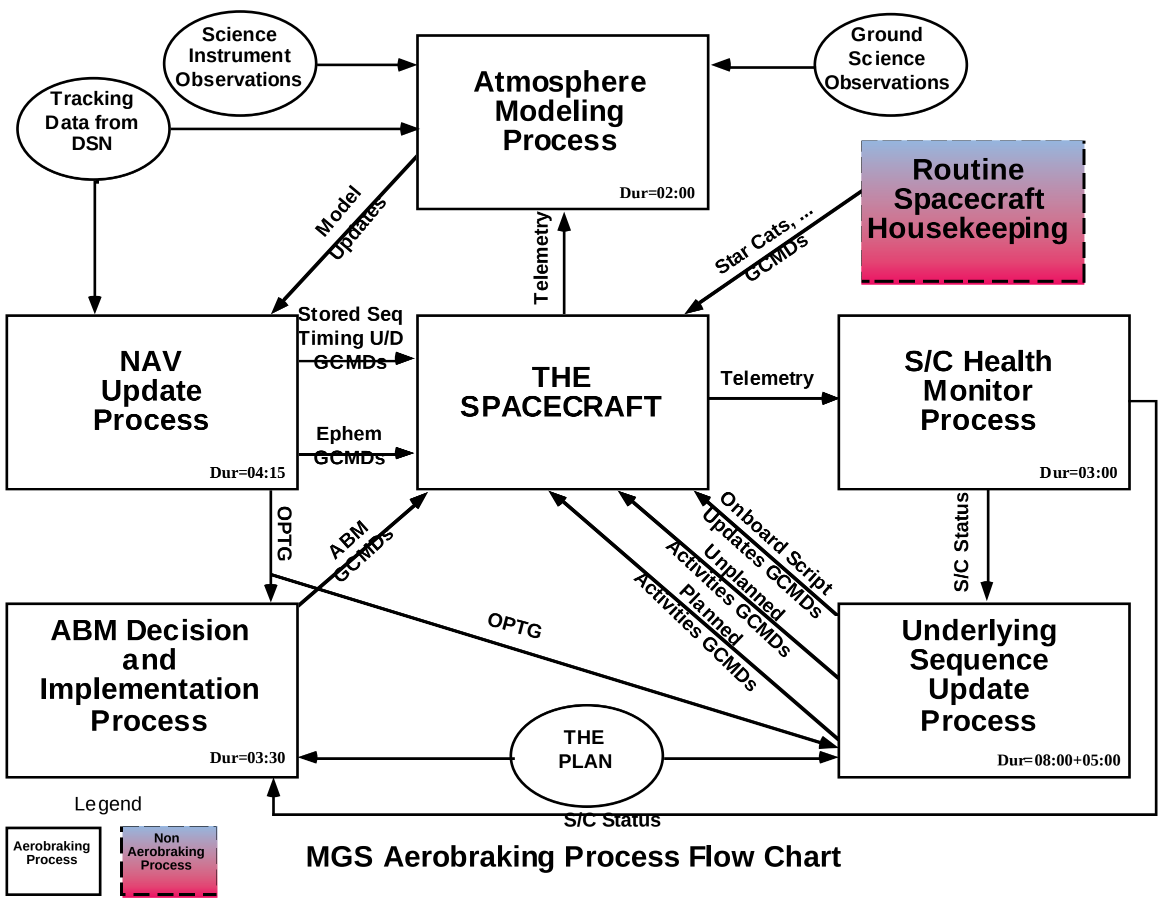
This process is used to monitor the daily health status of the spacecraft. It is a very simple and routine process which involves acquiring telemetry data from the spacecraft, analyzing those data and issuing reports pertaining to the health and status of the spacecraft. This process occurs daily during prime shift and requires approximately 3 hours to complete. The participating team is the SCT.

1.6 Atmosphere Modeling Process

This process is used to update the most current model being used for the Mars atmosphere. This process will analyze and review the existing Mars atmospheric model in use by the project, Mars Pathfinder atmospheric data, NAV provided atmospheric density data and SCT thermal and acceleration data to determine a more accurate model for the atmosphere. This new model will then be incorporated into the ABM Decision and Implementation Process to make possible the generation of updated Navigation files containing periapsis predictions for use during the NAV Update Process. This process will be used very infrequently.

All of the above processes must integrate together in a manner such that they do not require greater resources than are available on the flight team. Some processes are triggered by orbital geometric events (periapsis or apoapsis) while others are triggered by availability of certain data. Still other processes are performed off-line and will therefore always be performed during prime shift. During the earlier phases of aerobraking most processes will be able to be performed during prime shift. Those which cannot will still only occur once per day and will require some personnel to work a modified single shift per day. However, once the orbital period is less than 24 hours some processes will be performed more than once per day. This will require more than one shift support per day for some teams. As the end of aerobraking approaches, the flight team will be working three shifts per day. This three shift per day period should last approximately one month.

Figures 1.0 through 1.16 display these processes in a graphical format.



MGS Aerobraking Process Flow Chart

Figure 1.0

AB1 & TMO DESIGN PROCESS

THIS PROCESS IS PERFORMED IMMEDIATELY BEFORE AB1 AND TMO MANEUVERS

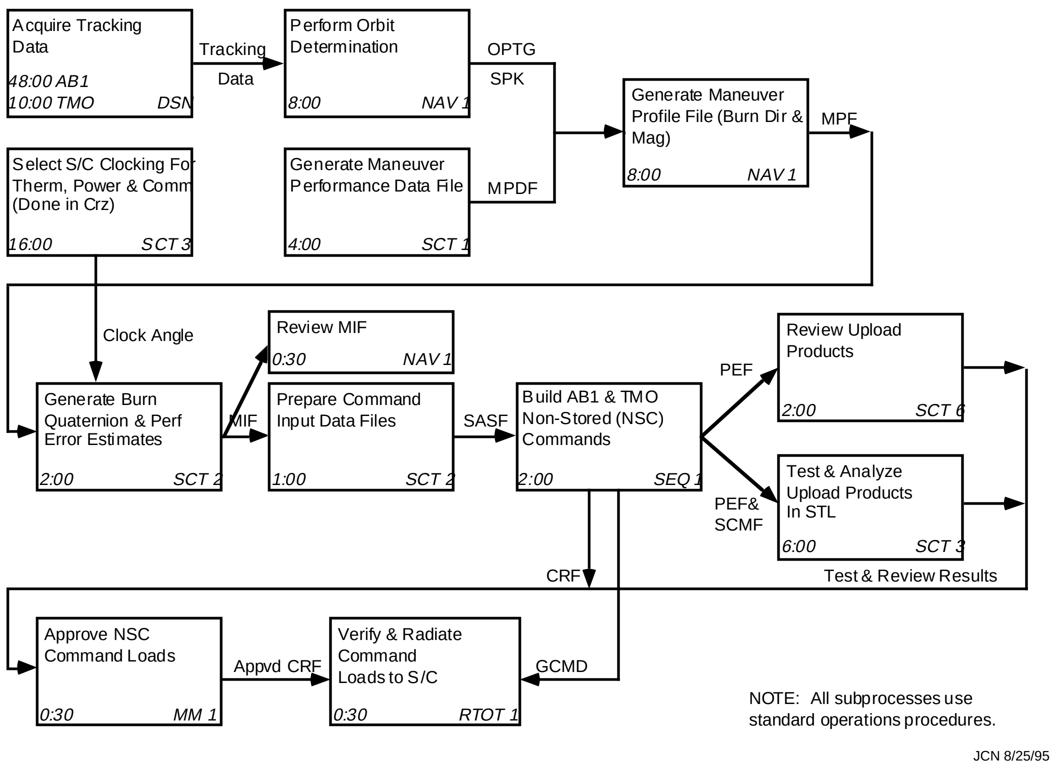
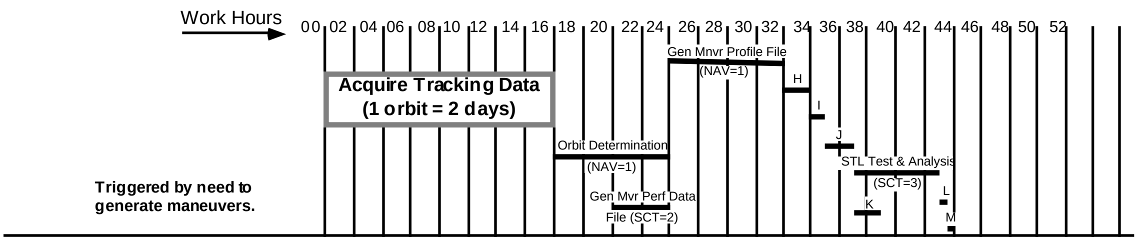


Figure 1.1

Aerobraking Operations Event Timeline

Aerobrake AB1 & TMO Maneuver Design Process



NOTE: Selection of S/C Clocking for Thermal, Power & Comm considerations is done during Cruise. Assume skeleton sequence SASF built prior to MOI. Process (I) updates the actual maneuver direction and magnitude to skeleton.

H) Generate Mnvr Implementation File (SCT=2)
I) Update Skeleton SASF (SCT=2)
J) Generate Maneuver Seq Products (SEQ=1)
K) Review Files (SCT=6)
L) Approve Maneuver Load (MM=1)
M) Radiate Maneuver Load (RTOT=1)

Duration: 28 Work hours (excluding tracking data acquisition)

Participating Teams: SCT, NAV, SEQ, RTOT.

Use Frequency: Performed realtime as needed to generate new maneuvers.

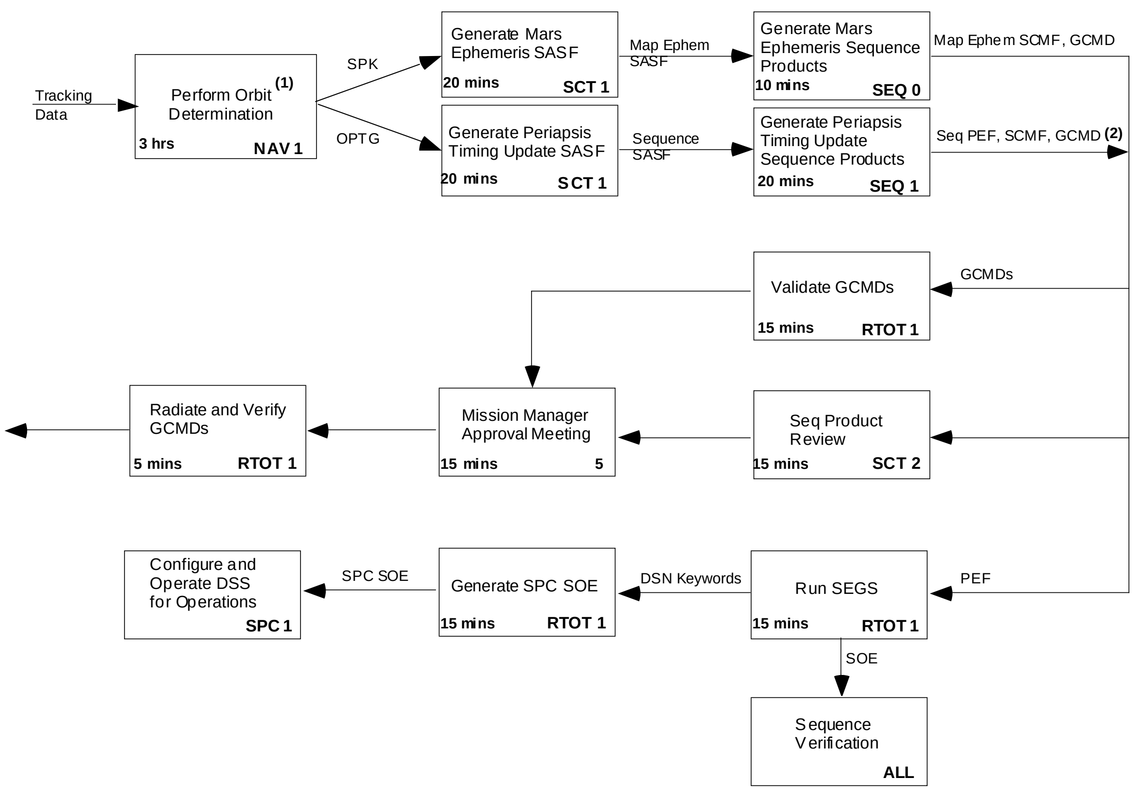
Process Functionality: This process is invoked when it becomes necessary to generate AB1 and TMO Maneuvers.

Inputs: Tracking data, S/C performance data.

Outputs: Maneuver Sequence files.

Figure 1.2

NAVIGATION UPDATE DEVELOPMENT PROCESS



PROCEDURE LIST FOR NAVIGATION UPDATE DEVELOPMENT PROCESS

All subprocesses within the Navigation Update Development process utilize standard operating procedures, with the exception of the following procedures which have been developed exclusively for aerobraking operations

Update ABM and/or AEROBRAKE Master Script SASFs

NAV-0015 Determine Atmospheric Density Model Parameters
NAV-0016 Determine Mars Gravity Field Model Coefficients

Generate Periapsis Timing Update SASF

SCT-0009 Sequence Timing Update

Figure 1.3

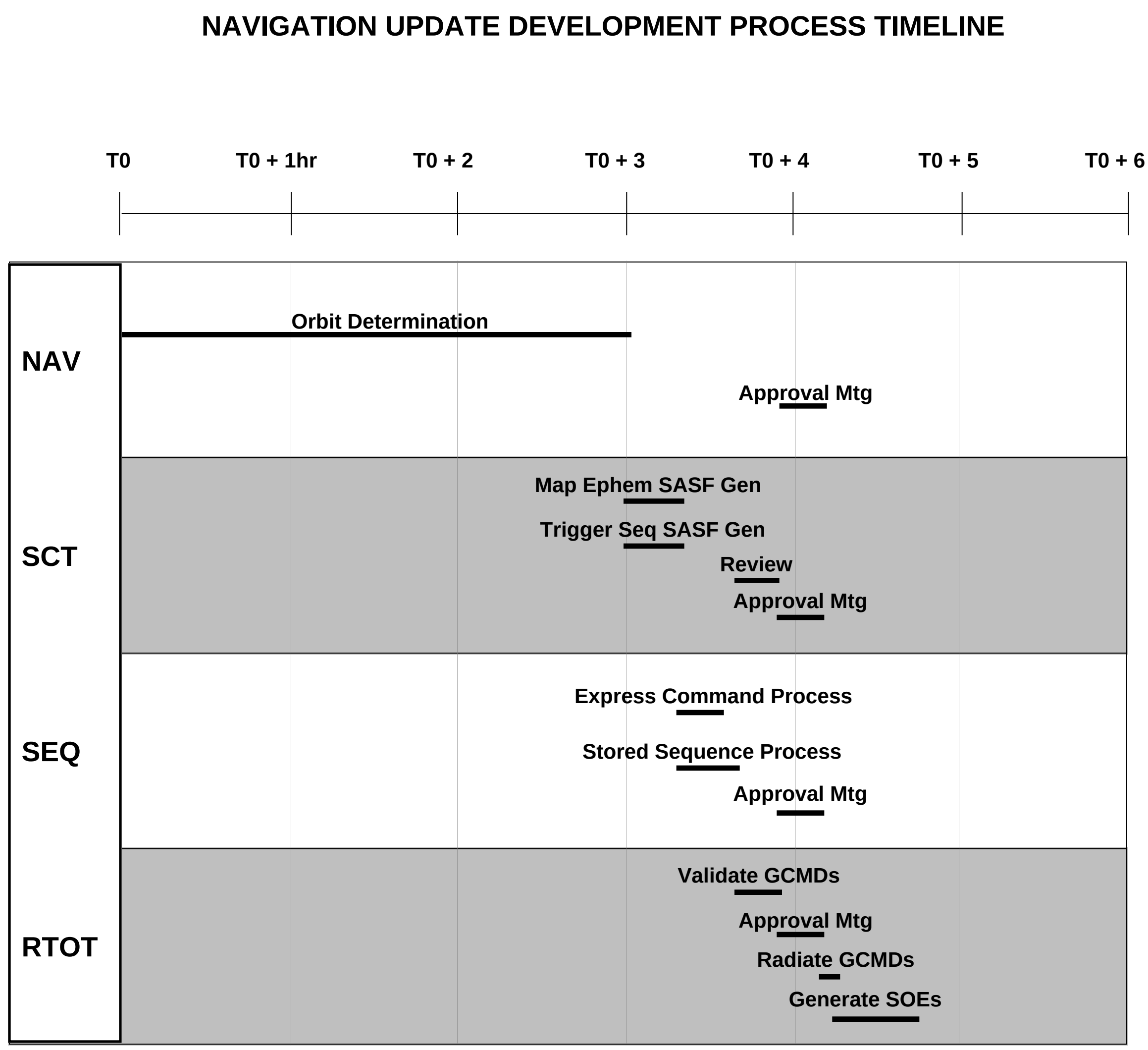
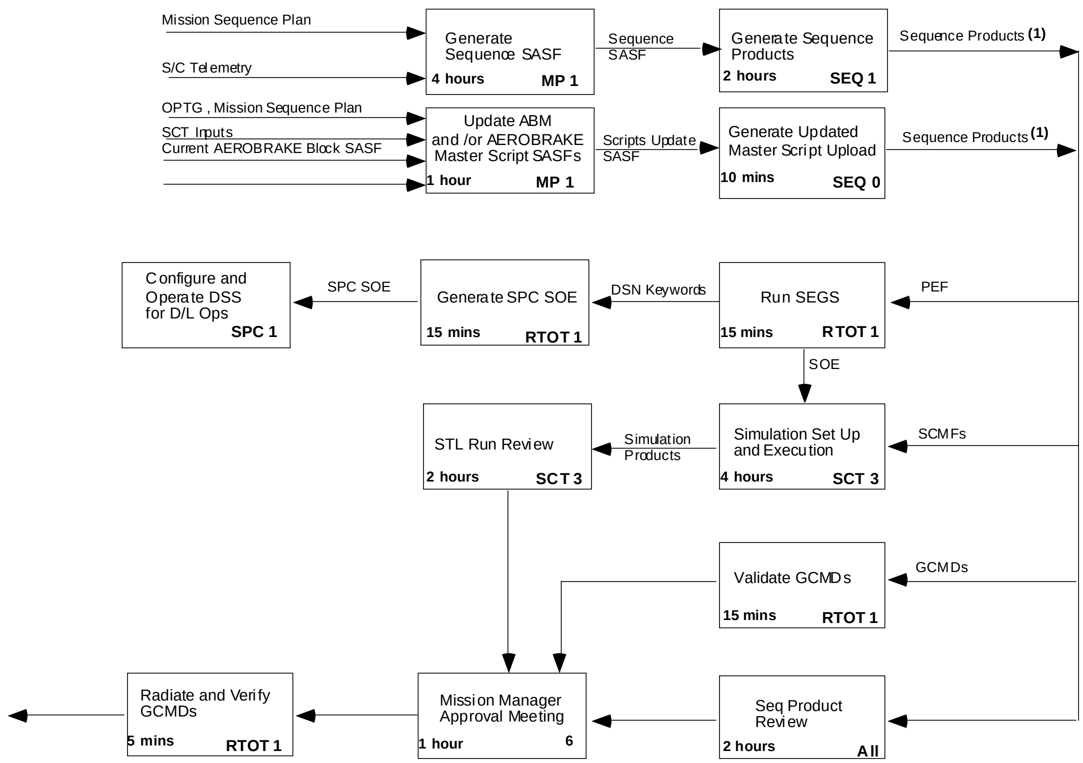

NAVIGATION UPDATE DEVELOPMENT PROCESS TIMELINE
T0
T0 + 1hr
T0 + 2
T0 + 3
T0 + 4
T0 + 5
T0 + 6
NAV
Orbit Determination
Approval Mtg
SCT
Map Ephem SASF Gen
Trigger Seq SASF Gen
Review
Approval Mtg
SEQ
Express Command Process
Stored Sequence Process
Approval Mtg
RTOT
Validate GCMDs
Approval Mtg
Radiate GCMDs
Generate SOEs

Figure 1.4

AEROBRAKING UNDERLYING SEQUENCE DEVELOPMENT PROCESS



Notes:

(1) Sequence Products consist of SASF, PEF, SCMF, GCMD, SEQTRAN Runlog, MEMMAP.

PROCEDURE LIST FOR UNDERLYING SEQUENCE DEVELOPMENT PROCESS

All subprocesses within the Underlying Sequence Development process utilize standard operating procedures, with the exception of the following procedure which has been developed exclusively for aerobraking operations

Update ABM and/or AEROBRAKE Master Script SASFs
MP-0002 Update Aerobrake Block Parameters

Figure 1.5

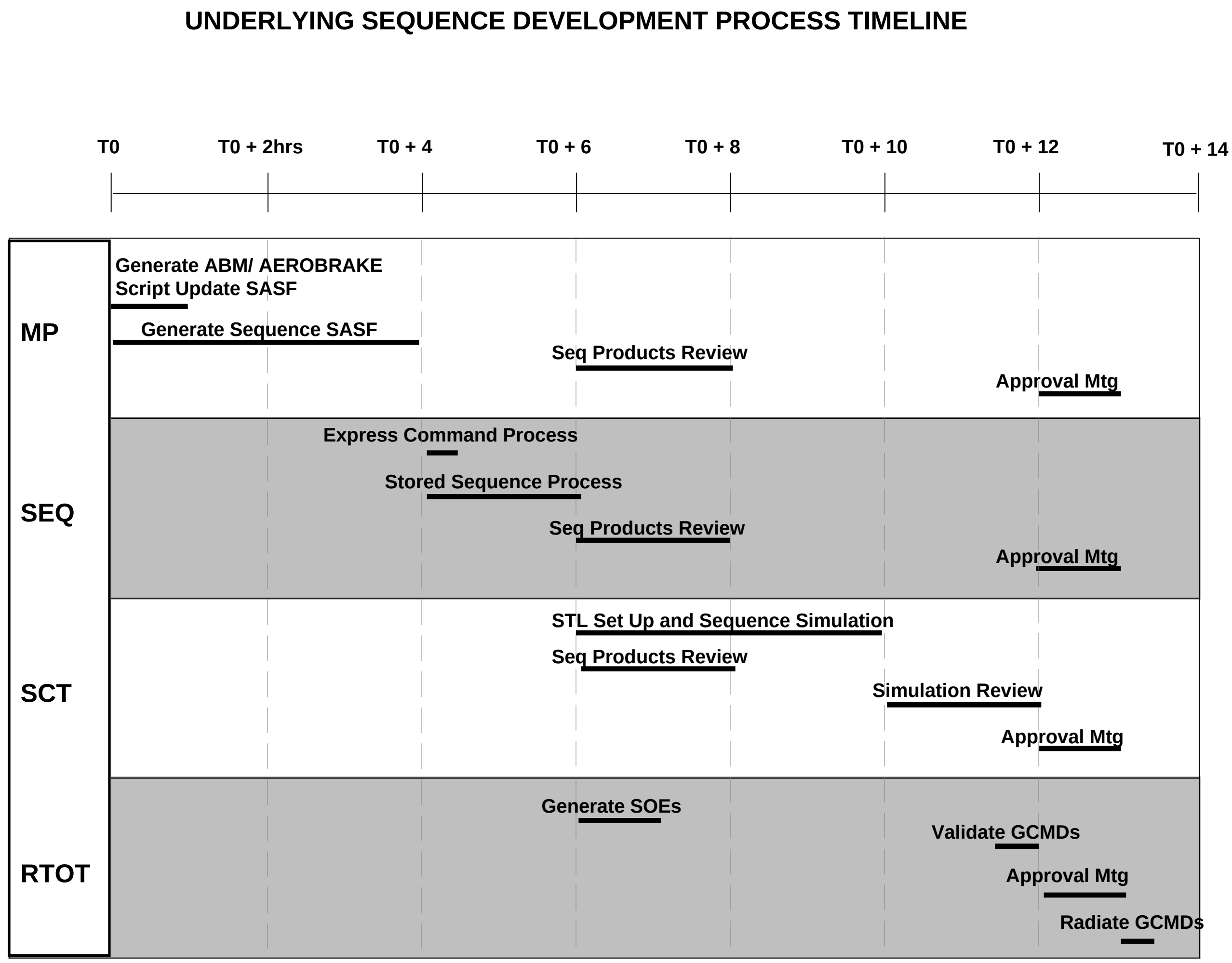
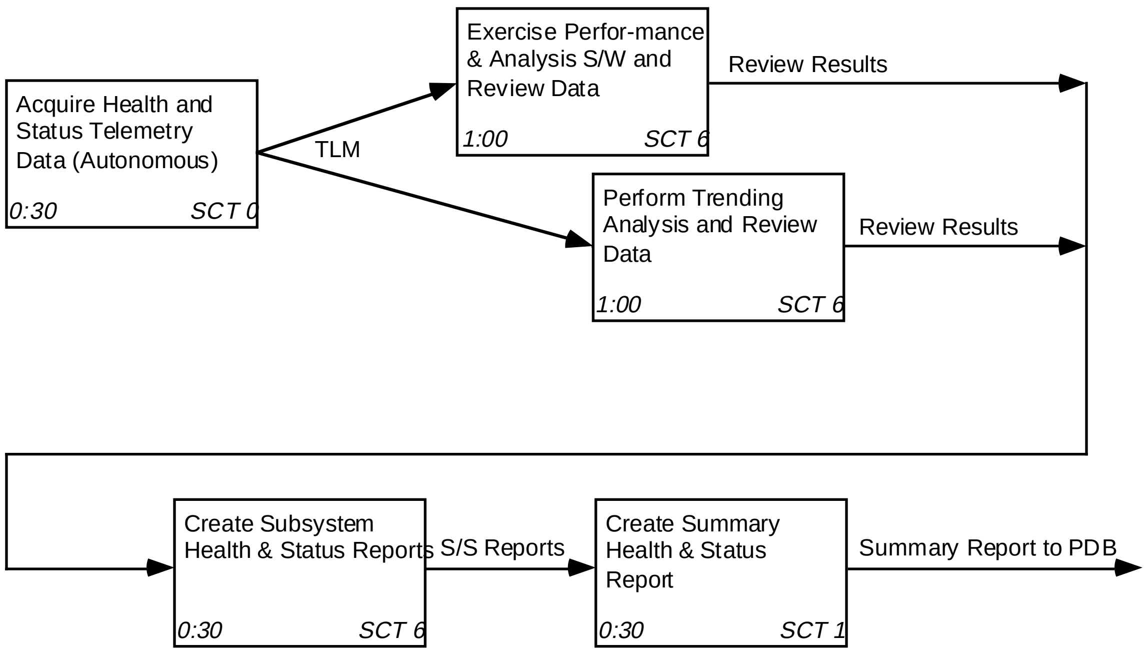

UNDERLYING SEQUENCE DEVELOPMENT PROCESS TIMELINE
T0
T0 + 2hrs
T0 + 4
T0 + 6
T0 + 8
T0 + 10
T0 + 12
T0 + 14
MP
Generate ABM/ AEROBRAKE Script Update SASF
Generate Sequence SASF
Seq Products Review
Approval Mtg
SEQ
Express Command Process
Stored Sequence Process
Seq Products Review
Approval Mtg
SCT
STL Set Up and Sequence Simulation
Seq Products Review
Simulation Review
Approval Mtg
RTOT
Generate SOEs
Validate GCMDs
Approval Mtg
Radiate GCMDs

Figure 1.6

SPACECRAFT HEALTH MONITOR PROCESS

THIS PROCESS IS PERFORMED DAILY



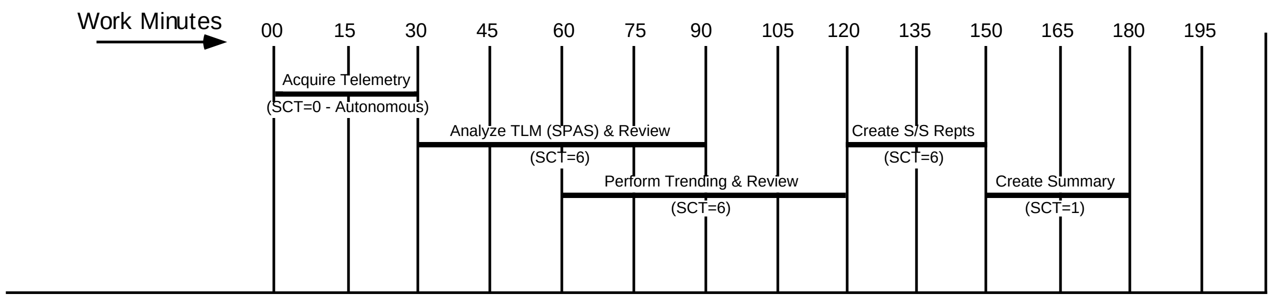
NOTE: All subprocesses use standard operations procedures.

JCN 8/25/95

Figure 1.7

Aerobraking Operations Event Timeline

Spacecraft Health Monitor Process



Duration: 3 Work hours

Participating Teams: SCT.

Use Frequency: Performed realtime daily.

Process Functionality: This process is invoked to evaluate spacecraft performance.

Inputs: S/C telemetry data.

Outputs: Spacecraft Status Report on PDB.

Figure 1.8

NAVIGATION PROCESS : ATMOSPHERIC DENSITY MODEL

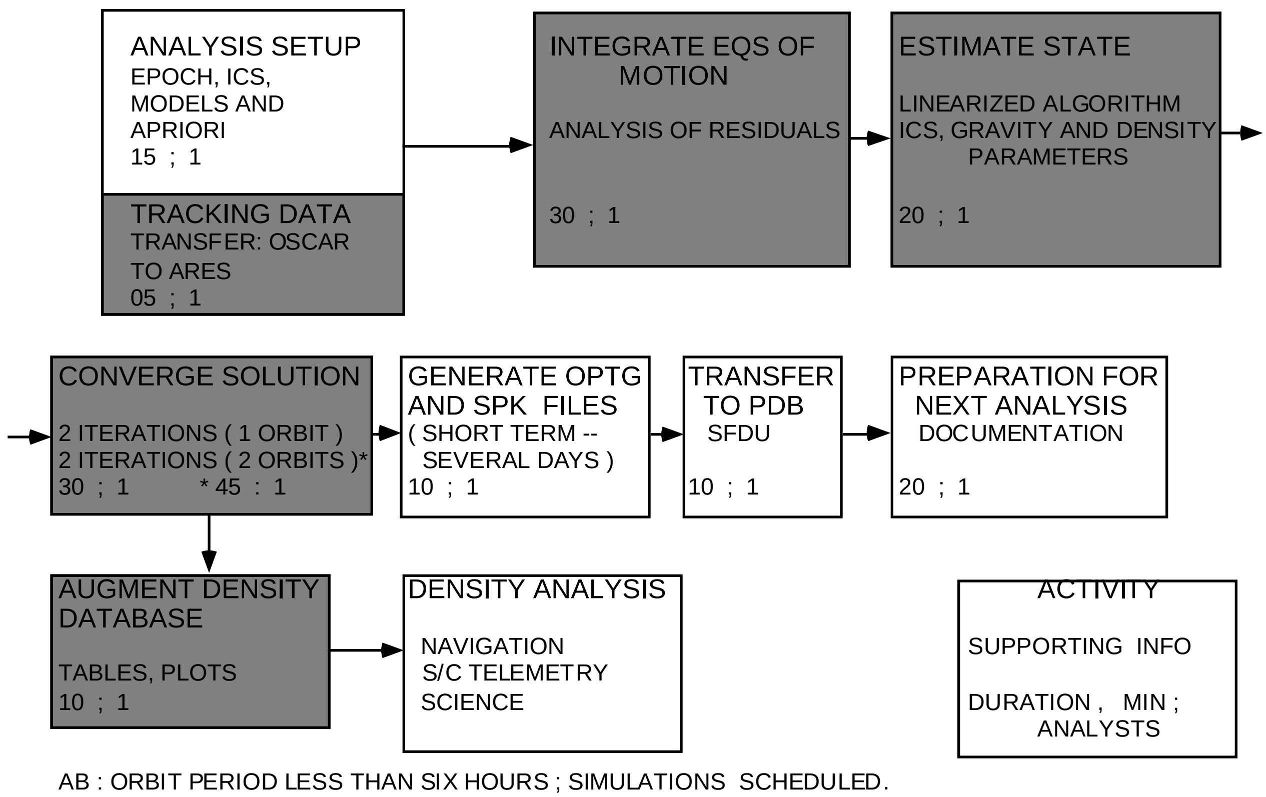
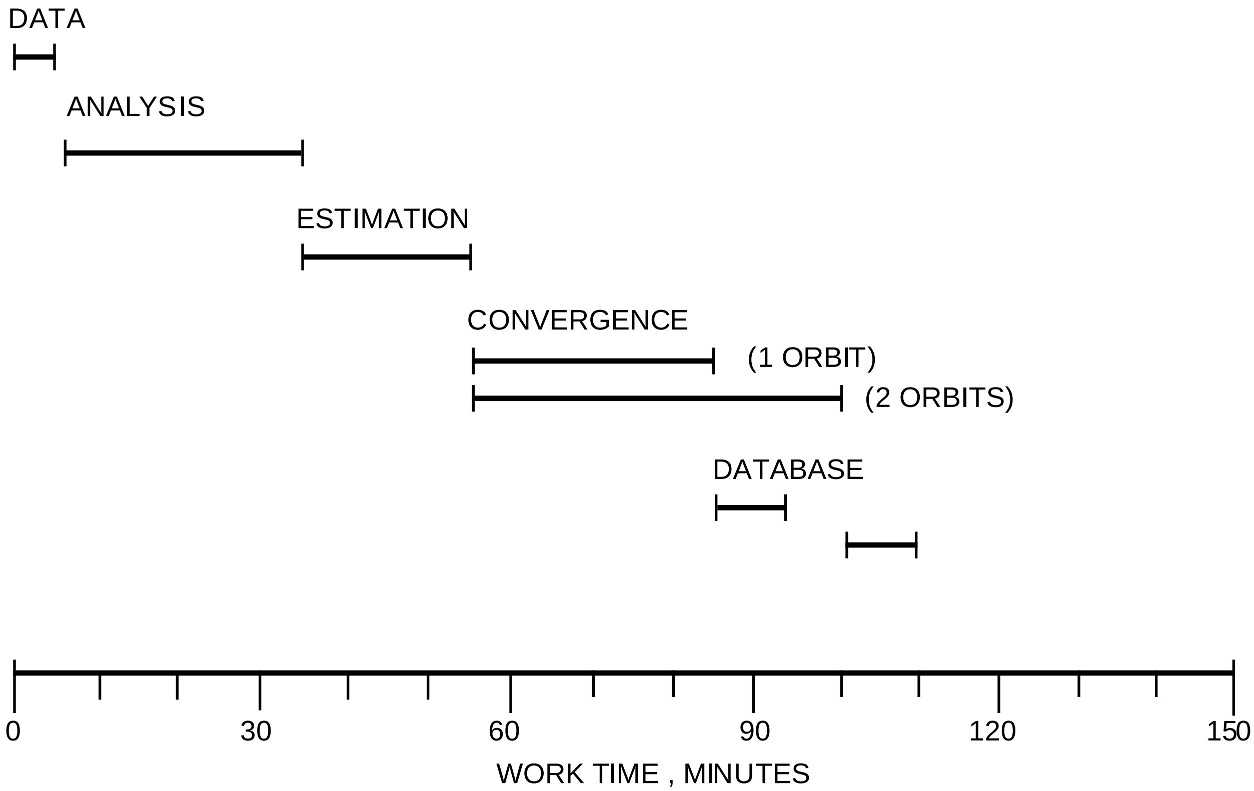


Figure 1.9

NAVIGATION PROCESS : ATMOSPHERIC DENSITY MODEL TIMELINE



PROCESS FREQUENCY
1. EVERY ORBIT FOR SINGLE ORBIT ANALYSIS
2. EVERY N ORBITS FOR MULTIPLE ORBIT ANALYSIS (GENERALLY N = 2)
AB: ORBIT PERIOD LESS THAN SIX HOURS

Figure 1.10

ABM Decision & Implementation Process

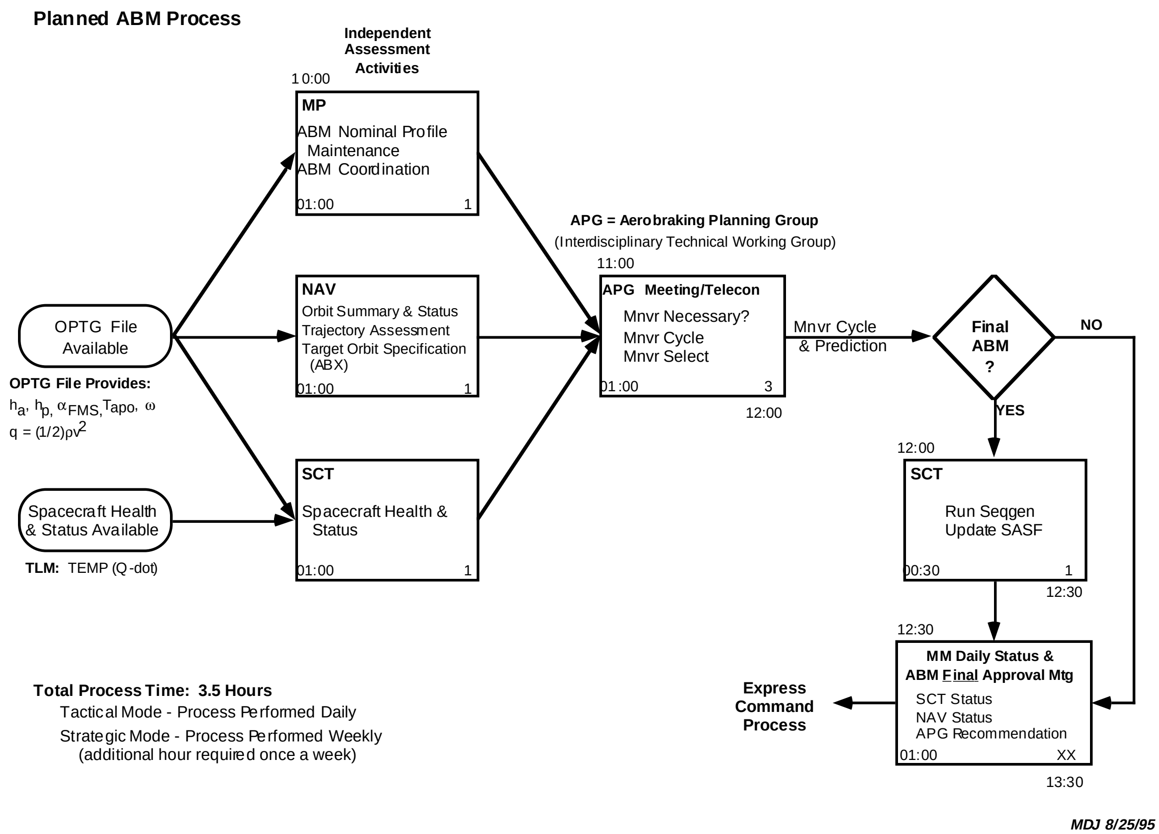


Figure 1.11

ABM Decision & Implementation Process
Event Timeline

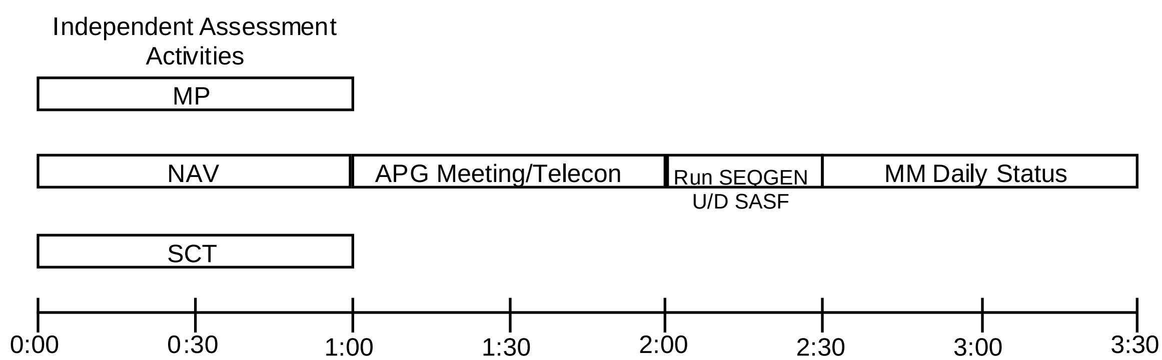
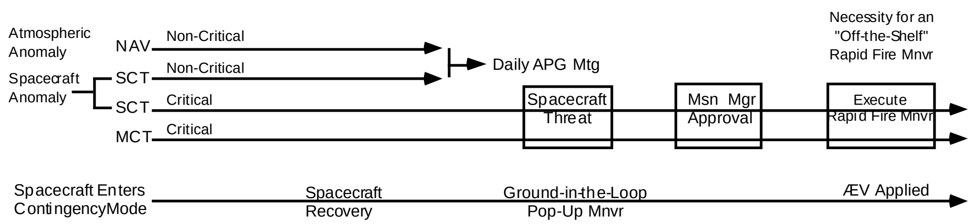


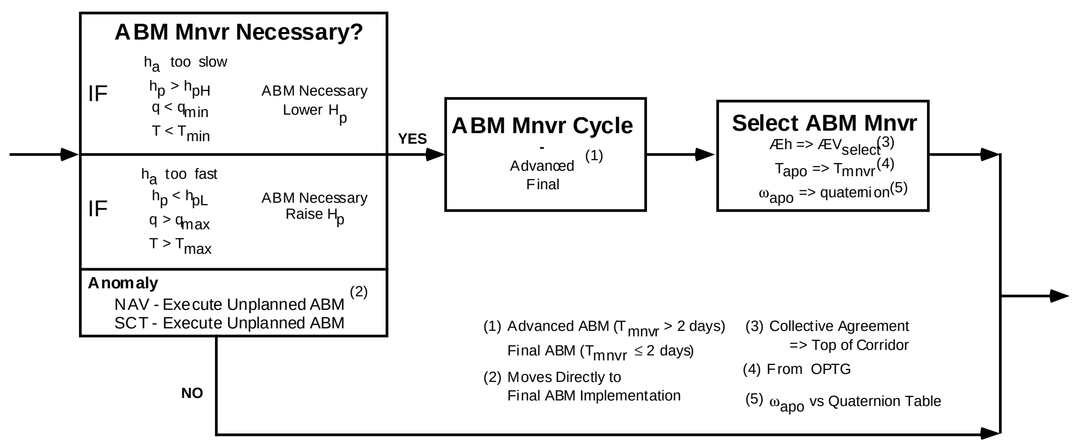
Figure 1.12

ABM Decision & Implementation Process (continued)

Unplanned ABM Process



APG Meeting/Telecon



Procedure List For ABM Decision & Implementation Process

All subprocess within the ABM Decision & Implementation Process utilize standard operating procedures,
with the exception of the following procedures which have been developed exclusively for aerobraking operations.

MP-0001 Aerobraking Planning Group
NAV-0015 Determine Atmospheric Density Model Parameters
NAV-0017 Guidelines for Propulsive Maneuver Selection
NAV-0018 Maintain and Update Navigation Aerobraking Database
SCT-0105 Aerobraking Planning Group

Figure 1.13

Aerobraking Metrics
"Glide Slope"

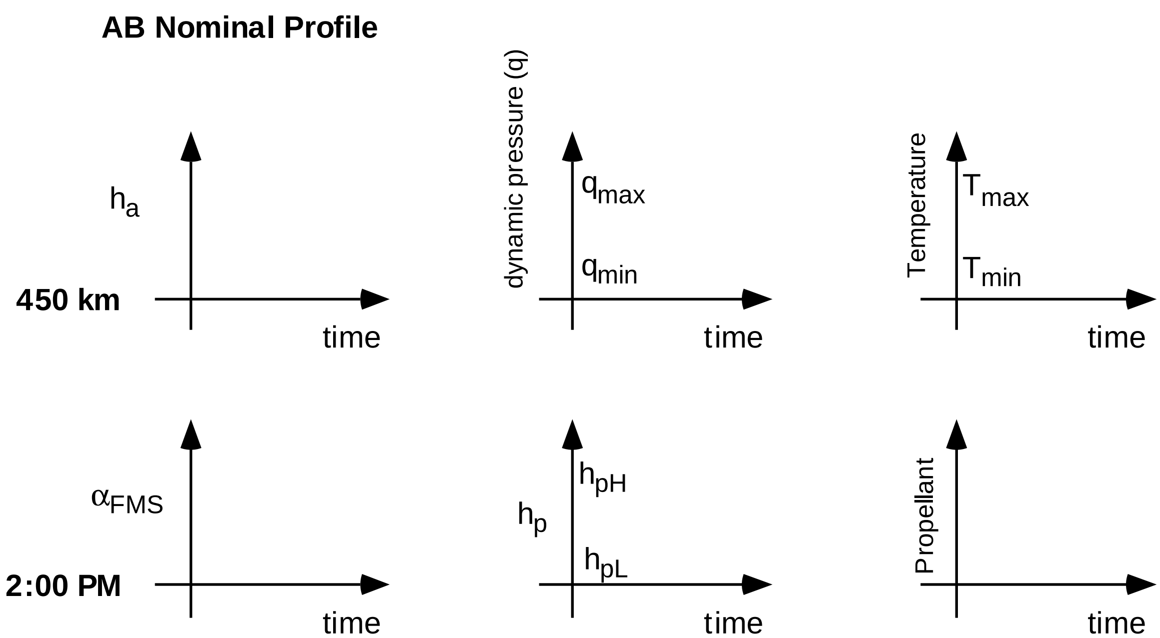


Figure 1.14

ABM DESIGN PROCESS

THIS PROCESS IS PERFORMED AN ESTIMATED 10 TIMES DURING CRUISE IN ADVANCE OF AEROBRAKING INITIATION

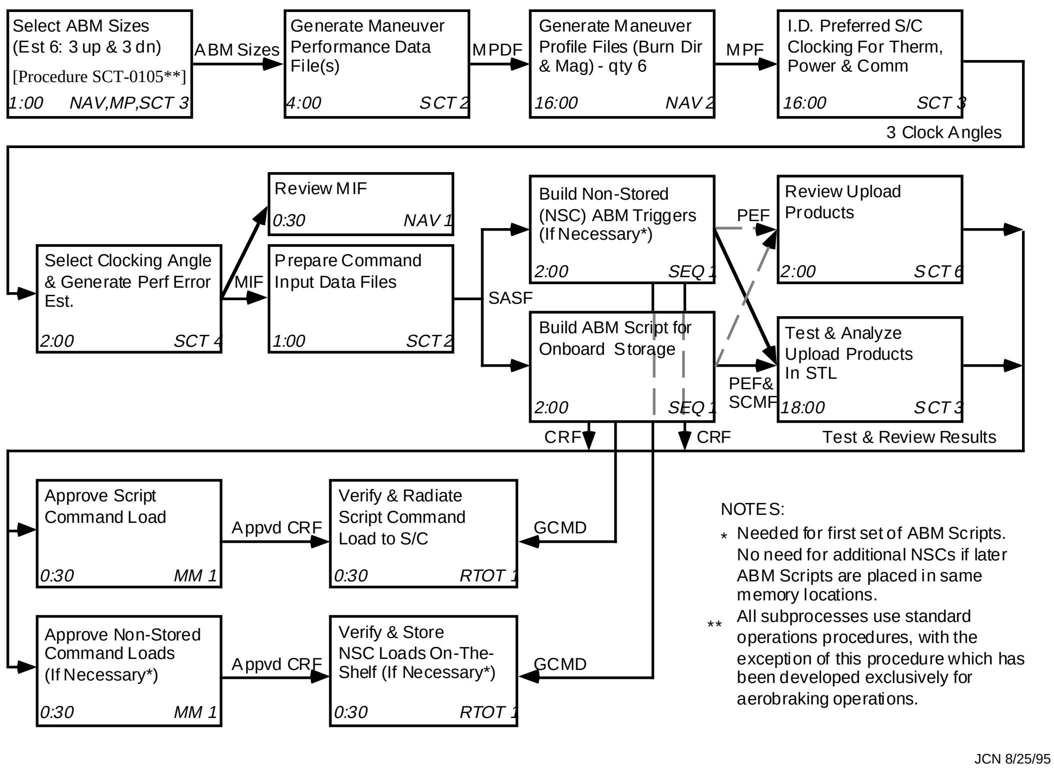
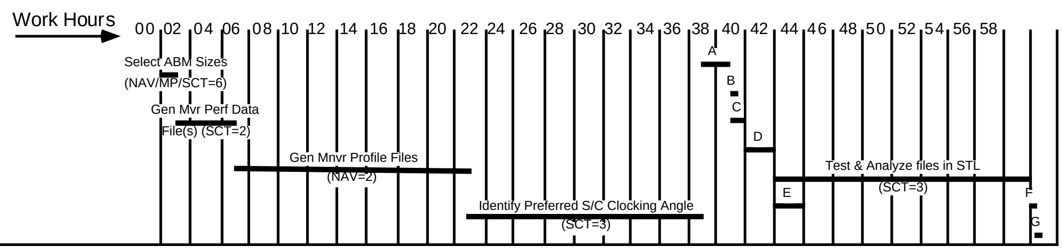


Figure 1.15

<u>Aerobraking Operations Event Timeline</u>

Aerobrake Maneuver (ABM) Design Process



NOTE: Approximately 10 sets of maneuvers are anticipated due to the variations in periapsis lattitude (~70°) and orbit plane (~60°) over the course of aerobraking.

A) Generate Mnvr Implementation File (SCT=4)
B) Check MIF (NAV=1)
C) Update Skeleton SASF (SCT=2)
D) Generate Maneuver Seq Products (SEQ=2)
E) Review Files (SCT=6)
F) Approve Maneuver Load (MM=1)
G) Store/Radiate Maneuver Load (RTOT=1)

<u>Duration</u>: 61 Work hours

<u>Participating Teams</u>: SCT, NAV, MP, SEQ, RTOT.

<u>Use Frequency</u>: Performed during cruise over 4 month period.

<u>Process Functionality</u>: This process is invoked to generate ABM maneuver menu.

<u>Inputs</u>: Aerobraking plan, S/C performance data.

<u>Outputs</u>: Maneuver Sequence files.

Figure 1.16

ACRONYM LIST

ACT	Automatic Command Toolkit
ASTD	ASCII Spacecraft Tracking Data file
ATDF	Archival Tracking Data File
CAR	Common Anomaly Report
CC	Coordinated Command
CCB	Change Control Board
CCL	Channel Conversion Language
CM	Configuration Management
CMA	Configuration Management Administration
CMS	Configuration Management Subprocess
CPM	Command Planning Meeting
CR	Change Request
CRA	Change Request Approval
CRF	Command Request Form
CSA	Celestial Sensor Assembly
CTDB	Command Tracking Data Base
CV	Command Verification
DKF	DSN Keywords File
DN	Data Number
DMR	Detailed Mission Requirements
DR	Discrepency Report
DSN	Deep Space Network
DSN	Deep Space Network Operations Team
DSOT	Data System Operations Team
EAE	Engineering Analysis Element
EC	Express Command
ECR	Engineering Change Request
ECRF	Electronic Command Request Form
EFRF	Electronic File Release Form
EPEF	Enhanced Predicted Events File
EU	Engineering unit
FR	Failure Report
FRF	File Release Form
FSA	Flight Software Analysis
FSPA	Flight System Performance Analysis
FSW	Flight Software
GCMD	Ground Command File
GSMCC	Ground System Monitor, Control and Configuration process
GDS	Ground Data System
GIN	Navigation constants and models file
IDSRD	Investigation Description and Science Requirements Document
ISA	Incident Surprise Anomaly report
LAN	Local Area Network
LT	Light Time

LM	Lockheed Martin
MAG/ER	Magnetometer/Electron Reflectrometer
MCT	Mission Control Team (part of RTOT)
MEP	Mars Exploration Program
MGS	Mars Global Surveyor
MIF	Manuever Implementation File
MM	Mission Manager
MMR	Monthly Management Report
MOA	Mission Operations Assurance
MOC	MGS Orbiter Camera
MOI	Mars Orbit Insertion
MOLA	MGS Orbiter Laser Altimeter
MOS	Mission Operations System
MOSIC	MOS Interactive Command
MGSO	Mission Operations Systems Office
MPDF	Maneuver Performance Dta File
MPF	Maneuver Profile File
MR	M ars Relay
MRR	Mission requirements Request
MSA	Mission Support Area (usually remote from JPL)
MSP	Mission Sequnce Plan
NAIF	Navigation Ancillary Information Facility
NAV	Navigation Team
NSC	Non-stored Commanding
NIPC	Non-interactive Payload Command
OD	Orbit Determination
ODF	Orbit Data File
ODP	Orbit Determination Program
OPTG	Orbit Propagation and Timing Geometry file
OTM	Orbit Trim Manuever
PAC	Pre-approved Commands
PDB	Project Database
PDS	Payload Data System (also Planetary Data System)
PEF	Predicted Events File
PFOC	Problem Failure Reporting System
PMR	Project Monthly Report
POSA	Project Operations Support Area (at JPL)
RS	Radio Science
RTLT	Round Trip Light Time
RTOT	Real-Time Operatins Team
SASF	Spacecraft Activity Sequence File
S/C	Spacecraft
SCIT	Sspacecraft-interactive Commands
SCT	Spacecraft Team
SCMF	Spacecraft Command Message File
SDA	Science Data Analysis
SEG	Sequece of Events Generation
SEQ	Sequence Team
SFOS	Space Flight Operations Schedule

SIE	Sequence Intergration Engineer
SOE	Sequence Of Events
SOPC	Science Operations Planning Computer
SOT	Science Operations Team
SPK	Spacecraft Plaetary Ephemeris Lernel
SSR	Solid State Recorder
STL	Spacecraft Test Labratory
UOE	Uplink Operations Engineer
TDL	Template Description Language
TES	Thermal Emission Spectrometer
TMOD	Telecommunications and Mission Opertions Directorate
TOL	Time Ordered Listing
TSAC	Tracking System Analytical Calibration
UOE	Uplink Operations Engineer